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The Origin of Cultivated Barleys: A Discussion[1]

G. STAUDT[2]

Introduction

Two hypotheses were considered by De Candolle (1883) for the origin of the cultivated six-rowed tough-rachis barleys (*Hordeum vulgare*): first, that the six-rowed barleys arose in early prehistoric agriculture from the two-rowed *Hordeum distichon*, in which the wild brittle-rachis *H. spontaneum* was included; and second, that the six-rowed barleys may have been derived from a wild six-rowed form. It is obvious that De Candolle was in favor of the former hypothesis because a wild six-rowed barley was then unknown. This would mean that *H. spontaneum*, which had been described by Koch (1848), was considered as the ancestor of all cultivated barleys. The term six-rowed is applied in this paper to all barleys with fertile lateral spikelets irrespective of density of the spike. Another term often used in the same sense is many-rowed.

Since De Candolle, different students of the phylogeny of the cultivated barleys have supported each of these hypotheses, although with slight variations (cf. Åberg, 1940). From the morphological point of view, Schiemann (1932) concluded that the two-rowed barleys were reduced forms and formulated the hypothesis that a wild six-rowed brittle-rachis type should be considered as the ancestor of the cultivated six-rowed barleys and the wild two-rowed brittle-rachis *H. spontaneum* as well. This view was elaborated by Åberg (1940), who stated that phylogeny not only in the genus *Hordeum* but also in the whole tribe TRITICEAE Dumort. (=HORDEAE) has probably progressed by reduction within the inflorescence.

The discovery of a six-rowed brittle-rachis barley by Åberg (1938) in material collected by H. Smith in southwestern China was welcomed as proof for the proposed hypothesis. This barley was described by Åberg as *Hordeum agriocrithon*. Evolution of the six-rowed cultivated barleys could now be easily explained, but different hypotheses have been proposed for subsequent development of other barleys, especially the two-rowed types. Discussions and diagrams of various possible evolutionary steps are given by Åberg (1940) and Schiemann (1951). It has been the opinion of most investigators during the past 20 years that the general outline of the phylogeny of cultivated barleys was well understood (Åberg 1940, Brücher and Åberg 1940, Freisleben 1940a, Hoffman 1956, Schiemann 1948, 1951, Takahashi 1955, Zukovsky 1950). In recent years, however, several papers have been published which cast doubt on the almost universally accepted theory of the origin of cultivated barleys from a six-rowed brittle-rachis ancestor. Criticism of this theory has evolved from different points of view which reflect the various disciplines employed in research on the history and evolution of cultivated plants. Bakhteyev (1947) was the first to oppose the theory. He doubted the wild character of *H. agriocrithon* because of the lack of any differences between *H. agriocrithon*

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and certain plants which he found in offspring of artificial crosses between *H. spontaneum* and six-rowed *H. vulgare*. He also found a six-rowed brittle-rachis barley plant in an experimental plot of *H. spontaneum* and concluded that this occurrence could be explained only by spontaneous hybridization with six-rowed *H. vulgare*. Zohary (1959) doubted the spontaneity of six-rowed brittle-rachis barleys from Israel which were described by Kamm (1954) and by himself. Further he gave some arguments, based on the biology of seed dispersal, against the spontaneity of such plants. Arguments based on comparative morphology were presented by Bowden (1959). Helbaek's (1953, 1959) arguments were founded on his investigations of archaeological material of barleys from prehistoric sites of Jarmo, Iraq. The radiation experiments of Gustafsson (1957), Nybom (1953), Scholz and Lehmann (1958), and Stubbe and Bandlow (1946/1947) have shown that fully fertile six-rowed mutants can be obtained from two-rowed barleys.

Altogether these investigations demonstrate the possibility that the two-rowed *H. spontaneum* has been the starting point for evolution of cultivated barleys. It should be mentioned that this is the opinion also of Bakhteyev (1957), Bowden (1959), Helbaek (1959), and Zohary (1959). Since we are faced with two diametrically opposed hypotheses, it seems worthwhile to discuss the various papers in more detail.

Discussion

According to investigations of Åberg (1940) and of Brücher and Åberg (1950), *H. spontaneum* and *H. agriocrithon* can be crossed without any difficulty with each other and with all other taxa of section HORDEUM (= CRITHE Döll = CEREALIA Anders.). The F_1 hybrids are always fully fertile. From all published data concerning hybridization and also from results of cytological investigations (Morrison, personal comm., Staudt, 1960) it may be concluded that all taxa of section HORDEUM are very closely related. Some of these, however, have been described as distinct species. There is no question that all these taxa should be combined in one species *Hordeum vulgare* L. emend. as has been done by Bowden (1959). The final infraspecific classification needs to be revised in view of new information on the relationship of *H. spontaneum*, *H. agriocrithon*, and *H. vulgare* (Bowden, 1960). Therefore, no rank is attributed to *H. spontaneum* and *H. agriocrithon* in this paper.

In addition to the typical section (sect. HORDEUM), Nevski (1941) established five other sections. The species belonging to these are morphologically quite different from those of section HORDEUM. They are also genetically and cytologically distinct from *H. vulgare* emend. (Morrison, 1959, Morrison *et al.*, 1959, Morrison and Rajhathy, 1959). Their karyotypes are different, and the species can be crossed with *H. vulgare* only with difficulty. There is very little chromosome pairing in F_1 hybrids, which are usually sterile. According to Nevski (1941), all these undoubtedly wild species are of the two-rowed type (heterospiculate), i.e., the central spikelets of each triplet are fertile and the lateral spikelets are reduced, male, and without seeds. There are only occasional exceptions: in *H. bulbosum*, for example, seeds rarely form in the lateral spikelets.

Within section HORDEUM the two-rowed *H. spontaneum* is undoubtedly wild. From the wide geographical distribution of wild taxa, all of which are two-rowed, it may be concluded that the two-rowed type is a very old one. Considering the two-rowed character and morphology of all living *Hordeum* species it seems quite unrealistic to regard the six-rowed *H. agriocrithon* as an ancestral type. Bowden (1959) therefore considered *H. agriocrithon* as a mutant which

arose in the eastern part of the range of *H. spontaneum*. He does not object to the hypothesis of a phylogenetic trend in the TRITICEAE toward reduction within the inflorescence. However, this reduction is believed to have occurred much earlier in evolution, and now no primitive six-rowed plants exist.

In considering the recent arguments against the hypothesis that *H. agriocrithon* is a primitive wild form and is the ancestor of the cultivated barleys, we should first discuss the question whether or not *H. agriocrithon* is actually a wild entity.

Anyone inspecting a plot of *H. agriocrithon* before harvest would believe that these are cultivated plants because of their vigorous growth and great spikes closely resembling cultivated barley. In contrast, when the plants mature and dry, the spikes break spontaneously, and no one would claim that *H. agriocrithon* is a very efficient cultivated plant from the standpoint of seed harvest.

Three of the collections of *H. agriocrithon* from Tibet and the bordering province (Sikang) of southwestern China (Åberg 1938, Brücher and Åberg, 1950, Schiemann 1951) were discovered as solitary grains in samples of wheat and six-rowed naked barleys respectively. Two plants grown from samples from Taofu, Sikang were described by Åberg as the varieties *cuagriocrithon* and *dawoense* of *H. agriocrithon*. Progenies of these plants showed a delayed germination, the grains were narrow and thin, and the weight per 1000 grains was 27.8 and 29.8 g respectively (the weight of 1000 grains cultivated varieties varies from 30-50 g). It was believed that these and other characters indicated the wild nature of the plants. Other samples of *H. agriocrithon*, described by Freisleben (1943) from Lhasa, Tibet, require a different explanation. The weight of the original five samples varied from 11-77 g. These samples, which consisted almost exclusively of kernels of *H. agriocrithon*, must have been purchased in markets or storage houses because the expedition of Schäfer reached and stayed in Lhasa only during winter. The relatively high weight of each sample, the purity of each, and also the fact that the weights per 1000 grains were a little higher than those of Åberg's strains led Freisleben to think of them as a primitive, possibly semi-wild form which had been under cultivation as a forage crop. Members of the expedition noted that, in the higher parts of Tibet, barleys were cultivated as forage crops and that seed, therefore, had to be introduced every year from lower regions. In this regard the observations of Korshinsky (cited by Regel, 1917) may be of interest. In Transcaucasia, *H. spontaneum* occurred frequently in dense natural stands which were mowed and threshed by country people. The quality of the grains, however, was not high enough to justify its further use as a grain (or cereal?) crop. "But in its green state it is easily mowed and it gives then a forage crop of good quality and agreeable taste." *Hordeum agriocrithon* may have been used in a similar way by the inhabitants of the Tibetan plateau, a possibility already pointed out by Freisleben (1943) and by Hoffmann (1956), but rejected by Schiemann (1951). Because of the broad leaves and consequently high forage yield, cultivation of *H. agriocrithon* as a forage crop should be worthwhile. Hence it seems quite possible that *H. agriocrithon* occurs both as a primitive cultivated plant and as a weed. No final decision can be made because we lack field observations.

Six-rowed brittle-rachis barleys are not known exclusively from Tibet and southwestern China. In a sample of six-rowed barley collected by A. Scheibe in northern Afghanistan, a single plant with two-rowed brittle spikes was found. This plant produced offspring which included, among other types, six-rowed brittle-

rachis plants (Freisleben 1940b). The original plant was considered to be a spontaneous hybrid, six-rowed *H. vulgare* × *H. spontaneum;* plants of *H. spontaneum* occurred in that area frequently as a weed in cereal crop fields. Additional six-rowed brittle-rachis barleys have been described from Israel by Kamm (1954) and Zohary (1959), from Iran by Kuckuck (1956), and from Turkmenistan (USSR) by Bakhteyev (1959). All these collections are located within the range of the wild *H. spontaneum* and are in areas in which six-rowed barleys are cultivated. A thorough study of the *H. agriocrithon* types in Israel was made by Kamm (1954). In several places, Mt. Tabor, the Esdraelon and Beisan valleys and the Negev Mountains, six-rowed brittle-rachis barleys, some of them distinguished as *H. agriocrithon* var. *euagriocrithon* and *H. agriocrithon* var. *dawoense* Åberg, have been discovered growing together with *H. spontaneum* and various kinds of intermediates. *Hordeum proskowetzii,* which was described by Náběl ek (1929) and later transferred by Nevski (1941) as a variety to *H. spontaneum,* may be explained as such an intermediate form. These plants have two-rowed brittle-rachis spikes, but in contrast to the typical *H. spontaneum* they have awns 2-5 cm long in their lateral spikelets. They were found in Turkish Kurdistan and southwestern Iran.

Different types of the six-rowed plants were cultivated by Kamm (1954); some proved to be constant in their offspring whereas others manifested their hybrid nature by segregating. Among the wild collections, Kamm found a six-rowed brittle-rachis type comparable with Körnicke's *H. intermedium,* which he believed was of hybrid origin. Similar types had already been described by Schiemann (1951) from Tsela Dzong, Tibet. The lateral spikelets of the plants grown from the collected seeds were awnless to awn-tipped. It was possible to isolate a true breeding line of the former type, but offspring of other plants showed segregation. Length of awns on the lateral spikelets of some plants approached that of var *dawoense* of *H. agriocrithon.* The name *H. paradoxon* was proposed by Schiemann for this brittle-rachis, hulled *H. intermedium* type. This name was used by Takahashi (1955) and Hoffmann (1956) although it was not validly published.

Zohary (1959) reported more than 30 hybrid swarms between *H. spontaneum* and six-rowed *H. vulgare* from eastern Galilee and from the foothills of the Judaean Mountains. These hybrid swarms grew usually in abandoned fields, along roadsides, and in other disturbed places. All intermediates between parental types were observed, as were plants that could not be distinguished from *H. agriocrithon.* Although the brittle-rachis character suggests the wild nature of these six-rowed plants, the plants have never been found in natural habitats, but similar forms may have arisen many times in the past by hybridization. Zohary attributed the inability of six-rowed brittle-rachis barleys to establish wild populations to the inefficient function of a six-rowed barley triplet as a dispersal unit. The spreading lateral spikelets somewhat prevent the unit from entering the soil and becoming anchored. The spikelets of the two-rowed brittle-rachis barleys seem well adapted to soil penetration. Zohary, therefore, did not agree that *H. agriocrithon* is a relic prototype of the barleys and considered it as a product of hybridization.

A similar origin may be proposed for the six-rowed brittle-rachis *H. lagunculiforme* (nom. invalid.), which was reported by Bakhteyev (1959) from Turkmenistan. This taxon and *H. spontaneum* as well were found in fields or edges of fields in areas in which six-rowed barleys are cultivated. It is of great interest to note that *H. lagunculiforme* was described by Bakhteyev (1957) from archaeological excavations of carbonized grains from the

Crimea, Armenia, and Azerbaijan; the Azerbaijan collection has been dated between 3000 and 2000 B.C. The lateral spikelets of this form are pedicellate, as in *H. spontaneum* and in some two-rowed tough-rachis barleys (*H. distichon*). It has been shown by Åberg (1957) that six-rowed barleys with pedicellate lateral spikelets have been found in progenies after hybridization between two-rowed and six-rowed types.

The origin of all recently described six-rowed brittle-rachis barleys from western Asia can be explained by hybridization, but it may be questioned whether the original discoveries from southwestern China can also be explained in this way.

According to Freisleben (1940a) and Nevski (1941), *H. spontaneum* extends eastward only to the Hindukush and Bokhara; according to Vavilov (in Regel 1917) it also occurs in the Pamir region. East of the Hindukush in the oases of eastern Sinkiang (Chinese Turkestan) Vavilov (1931) found neither *H. spontaneum* nor other species normally associated with crop fields in western Asia. He considered the Pamir and Hindukush region to be an efficient barrier to west-east plant migration. But Sinkiang and Tibet are still botanically little known and *H. spontaneum* may perhaps be found there. Consequently, at the moment we cannot attribute the eastern Asiatic *H. agriocrithon* to hybridization that occurred in the Tibetan area. If it can be shown that *H. spontaneum* does not and has never occurred in this area, it may be assumed that these *H. agriocrithon* forms have been introduced from west of the Hindukush and are also of hybrid origin. As Hu (1958) has pointed out, some puzzling modern plant distributions are due to introductions or migrations along ancient trade routes between China and the cultural centers of western Asia and Europe. For example, a great many of central Asiatic, Mediterranean and European genera of the Compositae occurring in China today have been found in Tibet. This is not because of chance, but rather because Tibet lay on the main southern trade route from central Asia and the Orient to China (Hu 1958). Accordingly, for at least the past 2000 years there existed a direct connection between the area of possible origin of *H. agriocrithon* and the places of recent discovery in southwestern China. Grains of *H. agriocrithon* could have been easily introduced among other cereals and selected by the inhabitants for a special purpose, probably as a forage grass.

Because of its adaptability to very harsh climates barley is able to survive in cultivation under the severe conditions found in Tibet. It therefore has become the main food plant of the Tibetans who use barley flour to prepare their national food, tsamba. No doubt they have selected naked barleys in preference to hulled barleys, since the former can be milled more easily. Naked barleys therefore are grown almost exclusively in this area, and the hulled *H. agriocrithon* has not been able to compete as a food plant.

From the genetic point of view, there are no difficulties in deriving the six-rowed from the two-rowed barleys. The radiation experiments of Gustafsson, Stubbe and Bandlow, Nybom, and Scholz and Lehmann showed that fully fertile six-rowed types can originate by a single gene mutation. Two of these artificial mutants have been shown to be monogenic recessive (Scholz and Lehmann, 1958). It has not been investigated whether these genes are identical with the series of multiple alleles $V^t \rightarrow v$ which govern the development and fertility of the lateral spikelets. The gene V^t (*deficiens*) dominates incompletely over V, V^d (two-rowed) and v (six-rowed) (Woodward, 1949). It is well known that dominant mutations are much less frequent than recessive ones. There is therefore a much higher probability for a mutation

from two-rowedness to six-rowedness than in the reverse direction.

A valuable contribution to the solution of the problem of the evolution of cultivated barleys has been provided by archaeological investigations. The hypothesis of Schiemann and Åberg was in no small measure influenced by the findings of six-rowed barleys in prehistoric material from settlements of the Lake Dwellers in Switzerland and from Egyptian tombs. On the other hand, two-rowed barleys were known at that time only from later-dated findings which supported the idea of most students of barley evolution that the two-rowed barleys were derived forms. This idea has been changed in recent years. In the excavations at Jarmo in the uplands of Iraq-Kurdistan, Helbaek (1953, 1959) found only a two-rowed barley, which is similar to *H. spontaneum* but may have had a less brittle rachis and bigger grains. Helbaek interpreted the material as a transition stage from the wild *H. spontaneum* to the cultivated form. The prehistoric site at Jarmo is the earliest known village-farming community (Braidwood, 1958) and was probably built very near the beginning of the era of plant and animal domestication. By radio-carbon methods, the Jarmo site has been dated as most probably about 7000 B.C. When agriculture reached the lowlands of Mesopotamia and Egypt 2000 years later, the two-rowed barleys were replaced by a lax-eared form of six-rowed barley (Helbaek, 1959). Archaeological investigations cannot prove whether the step from two-rowed to six-rowed barley occurred first under cultivation or in nature, but it is probable that the former was the case.

Summary

For the past 20 years, it was thought that the six-rowed brittle-rachis *Hordeum agriocrithon* was the ancestral form of the cultivated six-rowed barleys and also the two-rowed brittle-rachis *H. spontaneum*. In recent years new data have provided ample evidence for revising this widely accepted theory.

A number of reasons are given for concluding that a type similar to the modern *H. spontaneum* was the ancestor of both the two-rowed and six-rowed cultivated barleys. The earliest proof of cultivation of a primitive two-rowed barley was found at Jarmo (7000 B.C.), a village situated within the present range of *H. spontaneum*. Six-rowed barley may have originated by a single gene mutation from cultivated two-rowed barley. Six-rowed barley first occurred in archaeological sites from the lowlands of Mesopotamia about 5000 B.C.

Hordeum agriocrithon does not seem to be a primitive form although it has a brittle rachis. In western Asia *H. agriocrithon* has been found only in areas where *H. spontaneum* occurs wild and six-rowed barleys also are cultivated. Nowhere has it been found growing in truly natural habits. The taxa described as *H. agriocrithon* Åberg, *H. lagunculiforme* Bakhteyev, and *H. proskowetzii* Nábělek are considered to be of hybrid origin. Hybridization of the six-rowed cultivated barleys with the ancestral *H. spontaneum* could have taken place many times in the past and undoubtedly still occurs where they grow together. The occurrence of *H. agriocrithon* in Tibet and Sikang is regarded as the results of introduction from western Asia, possibly in historic times.

Naked barleys may have arisen in several areas by gene mutation. Their present distribution is a result of human use and customs and does not necessarily designate the place of origin.

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JOURNAL ANNOUNCEMENT

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Experiments in Preserving and Revitalizing Pine, Onion, and Okra Seeds

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WILLIAM MANN, JR.,[2] and JULIAN C. MILLER[3]

Introduction

In view of the somewhat contradictory reports on the preservation of seeds at low temperatures (1, 2, 3, 4, 9, 10, 11) and the agricultural importance of seed preservation and revitalization, the following study on seed preservation and revitalization was undertaken. This study, started in 1954, was designed to explore general conditions for preserving seeds of long leaf pine (*Pinus palustris* Mill.) which are extremely sensitive to adverse storage conditions; to increase germinability by breaking dormancy; and to revitalize aged seeds. The idea for the preservation of seeds was to apply Kaloyereas' dehydrofreezing method (6) on pine seeds, and his starch phosphate treatment against rancidity (7) on onion and okra seeds. For restoring loss of viability of aged seeds various treatments were tried, among which ultrasonic treatment and soaking in extracts from fresh seeds or pollen were more extensively used. In the application of dehydrofreezing method to seed preservation the correlation between the moisture content of the seeds and the preservation of their viability had to be investigated.

Experimental Methods

Fresh long leaf pine seeds of the same lot (original moisture 18%) were dried to various levels of moisture content and stored at temperatures ranging from room temperature to 0°F. Among those stored at room temperature were some in which the air surrounding the seeds was replaced by CO_2 or by CO_2 plus a small amount of ethylene oxide. The latter treatment has been satisfactory in rough rice storage experiments (8). This first attempt to use carbon dioxide with ethylene oxide in pine seed preservation was not intended for quantitative measurements and had only exploratory purpose. In the use of antioxidants for the preservation of viability, okra and onion seeds were dipped for one minute in 1% starch phosphate solution or 1% emulsion of tocopherol in water with some alginate salt added to it. The controls were dipped for the same length of time in water. The moisture content of seeds (treated and controls) was brought up to the original level by drying them in the dehumidifier at room temperature. The treatment of aged seeds with water extract of fresh seeds consisted in placing the seeds in the extract overnight at 45°F. The ultrasonic treatment lasted from 15-30 minutes in a magnetostriction oscillator of 9 kilocycles or in a model U-300 Ultrasonator (of Televiso Company) with a frequency as high as 457 kilocycles. For the determination of germinability the standard "sand flat germination test" and a "tetrazolium chloride technique" developed in our laboratory were used. Germinability was tested by Mr. W. Mann at the Alexandria Research Center and by Kaloyereas at the Food Preservation Laboratory of Louisiana State University (Baton Rouge) with excellent agreement. Both methods gave similar values but only

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the data obtained with the standard method are presented here. At the food preservation laboratory tests were performed on 50-100 seeds in wooden cases filled with sand and kept near a northern window of the laboratory. All seeds were practically under the same light and temperature conditions and data given in the tables were taken so as to be comparable.

TABLE I

PER CENT GERMINATION OF PINE SEEDS AFTER DEHYDRATION TREATMENT.

Storage temp.	% germination at the start		
	18% moisture	13.5% moisture	8% moisture
78° F	78.3	----	----
34° F		84.3	84.3
25° F		82.0	82.0
0° F		78.3	78.3

Discussion and Results

From the existing literature on the effect of higher temperatures on life and the subsequent development of the organisms, one might suspect that drying by the usual methods would affect the viability of seeds. Even when the drying temperature or the length of the heat treatment is not such as to affect the life of the seeds, it certainly results in decreasing their power of germination. This becomes more apparent in a long storage and therefore should be taken into consideration. In order to reduce the influence of this factor to the minimum, a desomatic dehumidifier was used to dry seeds at room temperature.

In a previous paper on the role of rancidity in the loss of viability of fatty seeds (7), it was found that rancidity development correlates closely with the loss of viability in the early stage of loss of viability. This was attributed to the destruction of tocopherols and other antioxidants present in seeds. Tocopherols and other antioxidants are known to be associated with fertility and longevity (5). Therefore, if the hypothesis is correct, treatment of seeds with a proper antioxidant should have some protective effect on viability.

The results of five years' storage of pine seeds with the dehydrofreezing treatments suggest that there is a relationship between moisture level in the seeds and the storage temperature for optimum preservation (Table I). In general an 8% moisture level in the seeds proved to be the best for both 25°F and 0°F, but for a shorter period of preservation a higher level of moisture content (13.5%) is also satisfactory. At 25°F some of the water present in the seeds remains in the bound form but not at 0°F or below. In Table II and Graph I data obtained from storage at 0°F, 25°F, and 34°F are summarized.

Seeds stored at temperatures below freezing germinated more rapidly than seeds stored at temperatures above freezing (Table III). The results of the treatment of okra and onion seeds with antioxidants such as starch phosphate and

TABLE II

GERMINATION AND PERCENTAGE LOSS OF GERMINATION DURING STORAGE OF PINE SEEDS.

	18% moisture		13.5% moisture		8% moisture		
	Germination	Loss %	Germination	Loss %	Germination	Loss %	
78° F	0.0	78.3	----	----	----	----	
25° F			65.2	20.3	63.2	21.7	After one year storage
0° F			66.2	15.4	63.7	18.8	
34° F			65.8	21.9	64.0	24.0	After two years' storage
0° F			66.2	14.1	66.7	14.7	
34° F			20.0	76.2	55.0	34.7	After five years' storage
25° F			45.0	45.1	60.0	26.8	
0° F			62.0	20.8	65.0	16.9	

GRAPH I

COMPARATIVE RESULTS OF TREATMENTS IN PRESERVING VIABILITY OF OKRA, PINE AND ONION SEEDS

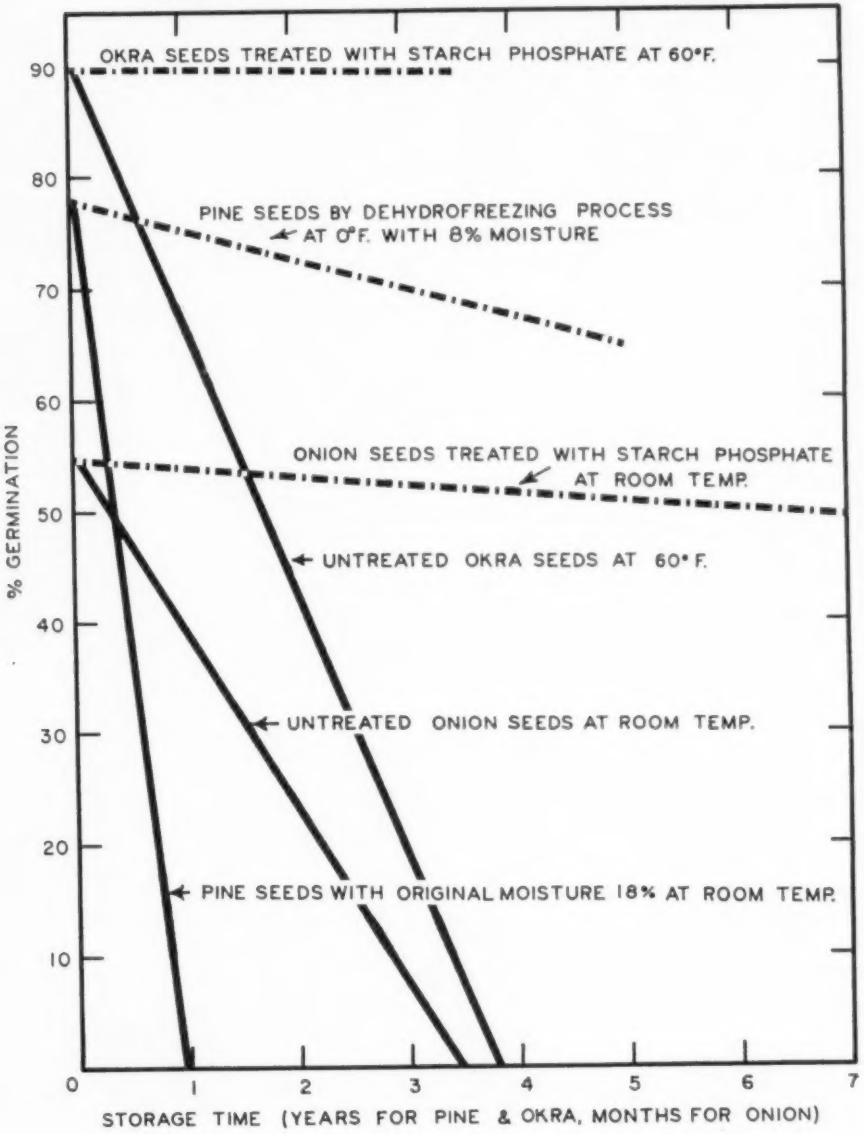

TABLE III

EFFECT OF FREEZING TREATMENT ON THE VIABILITY AND TIME OF GERMINATION FOR LONG LEAF PINE SEEDS.

Storage conditions and treatments	% moisture	% total germination	No. days required		
			To start germination	For 50% germination	To complete germination
Fresh seed	18.5	84.0	13	—	28
Fresh seed	10.0	81.0	12	—	28
Fresh seed	6.1	76.0	11	—	28
Stored seed					
45° F 1 year	18.5	48.0	14	16	30
Room temp. 1 year	5.5	18.0	16	20	33
0° F 1 month	18.5	94.2	5	7	20
25° F 1 month	18.5	94.0	5	7	20
25° F 1 year	12.9	32.0	10	11	14

α-tocopherol shown in Table IV support the proposed theory and demonstrate the beneficial effect of these treatments in the preservation of viability of onion and okra seeds.

Other results of this experiment are: (a) that pine seeds stored at temperatures below freezing germinate more rapidly than seeds stored at temperatures above freezing (Table III) and (b) that partial drying of seeds in a desomatic dehumidifier at a few degrees above room temperature had practically no effect on germination, (c) that the use of limited amounts of carbon dioxide with ethylene oxide for the preservation of viability in pine seeds would require a rather severe dehydration treatment to about 5% moisture, and (d) that carbon dioxide alone or even airtight containers improve the conditions of preserving viability of pine seeds at lower temperatures and lower levels of moisture content of the seeds.

Summary

Experiments on preserving seed viability showed that partial drying can extend the vitality of pine seed stored both above and below freezing temperatures. For long leaf pine seeds, drying to 8% moisture was beneficial in preserving viability at subfreezing temperatures; for

TABLE IV.

EFFECT OF TREATMENTS WITH STARCH PHOSPHATE AND α-TOCOPHEROL ON THE PRESERVATION OF VIABILITY OF OKRA AND ONION SEEDS.

A. Okra seeds ('Louisiana Market') stored at 60°F.

Treatments	Germination %			
	At the beginning	After 75 days	After 150 days	After 1270 days
1) Control	90	87	62	8
2) Treated with starch phosphate	90	97	88	92
3) Treated with *alpha*-tocopherol	90	72.5	—	—

B. Onion seeds ('Texas Grano') stored at room temp. (around 85°F) with and without treatment.

Treatments	Germination %				
	At the beginning	After 90 days	After 105 days	After 150 days	After 240 days
1) Control	55	37.0	0.0	0.0	0.0
2) Treated with starch phosphate	55	63.0	62.0	66.0	49.0
3) Treated with *alpha*-tocopherol	55	50.0	46.9	—	—

room temperature preservation, drying to 5% was preferable. A freezing treatment of pine seeds improves viability and also shortens the time needed for germination.

The viability of onion and okra seeds can be preserved for a long time at room temperatures by treating the seeds with starch phosphate; tocopherol treatment appears less beneficial.

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Ascorbic Acid Content and Time of Ripening of Tomatoes[1]

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Introduction

Fruits of the tomato (*Lycopersicon esculentum* Mill.) attain their full size before showing any signs of ripening. Commercially, full-sized tomatoes have been classified as mature-green or immature-green, depending upon the time required for ripening, although not all investigators agree with the dividing line between these categories. Clendenning (2) considers fruits mature-green if they ripen within 4 days; immature fruits require 5 to 21 days for ripening. Miller and Jablonski (13), using "green wrap" tomatoes, included in the mature-green category all fruits that ripened within 11 days while immature-green fruits required more than 11 and up to 22 days to ripen. It is possible that fruits picked for shipment would be harvested in a less mature stage than those harvested for a local market or for home use.

There is some difference of opinion regarding the changes in ascorbic acid content between green and ripe stages of maturing tomatoes. Several workers (3, 8) have claimed that there are no significant differences in ascorbic acid content of green and ripe tomatoes, while others (11, 15) have found differences. The difficulty is increased by the fact that there is considerable variability in the constituents of tomatoes from different plants, different positions on the same plant and even between different fruits from the same flower cluster (5).

We studied the changes in ascorbic acid content that occur in the ripening of green tomatoes, comparing immature-green with mature-green fruits, and developed a method that permitted following these changes in identical fruits.

Materials and Methods

Most of the tomatoes used in this study were 'Homestead' variety shipped as "green wraps" from Florida. All tomatoes were selected for uniformity in size and color and were cleaned superficially with 70% ethyl alcohol to remove surface contaminants. They were then cut in half longitudinally, weighed, and numbered. The cut surface of one half was coated with melted paraffin to prevent the entry of micro-organisms and reweighed to correct for the addition of paraffin. The uncoated half was placed in a waxed freezer carton and stored immediately at −17.7°C. The wax-coated half was placed inside a waxed translucent paper bag and allowed to ripen at 20°C constant temperature. The halves were examined daily for ripeness and were considered ripe when uniformly red. The weight of the ripe half and the time required for ripening were both recorded. The samples were frozen and subsequently used for analysis.

All analyses were made on samples which had thawed gradually at 5°C. The paraffin coating was removed, and the tomato was homogenized in 3% metaphosphoric acid in a Waring blendor. Total acid content was determined by titration of unaltered juice against 0.1 N NaOH, using phenolphthalein as the indicator. Ascorbic acid content was determined by titration against 2,6 dichlorobenzenone-indophenol (1). Statistical analyses were

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TABLE I
COMPARISON OF TOTAL ACID AND ASCORBIC ACID WITH RIPENING TIME IN GREEN AND RIPE TOMATO HALVES.

Experiment	No. of Fruits	Average Total Acid as citric (mg./100g.)		Average Ascorbic Acid (mg./100g.)		Aver. Days to Ripen
		Green	Ripe	Green	Ripe	
I	45	344.0	243.0	0.632	0.635	9.3
II	36	287.0	204.0	1.434	2.972	7.4
III	19	185.0	132.0	1.489	1.508	8.5
IV	15	187.0	137.0	0.678	2.099	7.7

made on ascorbic acid values, using the "t" method (18). The study was repeated four times during one year. A total of 115 tomatoes were analyzed.

Results

A comparison of the amount of ascorbic acid and total acid in green and ripe halves, along with the average ripening time, is presented in Table I. These results represent the average of four experiments.

Since it appeared that the half fruits which required less time to ripen contained relatively more ascorbic acid than those which required a longer ripening period, an average time was computed, and the ascorbic acid values above and below this line were compared. Table II shows the comparisons between green and ripe halves of fast-ripening tomatoes and slow-ripening tomatoes. Experiment I, for example, reveals that faster-ripening fruits contained much more ascorbic acid than the slower-ripening fruits.

In a further comparison, the ascorbic acid values of the fastest ripening tomatoes were compared with the slowest ripening tomatoes, combining the results of all four experiments (Table III). The results show that 17 tomato halves ripened in four to six days while 18 tomato halves ripened in 11 to 13 days. Although "t" value (18) was calculated on the results of individual samples, for brevity, the recorded ascorbic acid values are averages. The fastest ripening tomatoes showed a significant increase in ascorbic acid from the green stage to the ripe; the slowest ripening fruits showed no significant increase.

An effort was also made to detect differences in initial content of ascorbic acid of fast-ripening and slow-ripening fruits

TABLE II
AVERAGE ASCORBIC ACID CONTENT OF FAST-RIPENING AND SLOW-RIPENING TOMATOES

Experiment	No. of Fruit Halves	Days to Ripen	Ascorbic Acid (mg. per 100 g.)	
			Green	Ripe
I	8	Less than	0.673	1.964
II	26	8.3	1.470	3.221
III	11	days	1.095	1.213
IV	13		0.672	2.561
Over-all Average =			1.110	2.519
I	37	More than	0.733	0.318
II	10	8.3	1.413	2.619
III	8	days	2.180	1.929
IV	2		0.732	1.465
Over-all Average =			1.055	1.029

TABLE III
STATISTICAL ANALYSES OF DIFFERENCES IN ASCORBIC ACID BETWEEN FAST-RIPENING AND SLOW-RIPENING TOMATOES

No. of Fruit Halves	Ripening Time (Days)	Ascorbic Acid (mg./100 g.)		"t"	P
		Green	Ripe		
17	4-6	1.161	2.056	3.23	0.02-0.01
18	11-13	0.873	0.943	0.146	>0.90
		Slow Green	Fast Green		
34		0.873	1.161	0.616	0.60-0.50
		Slow Red	Fast Red		
34		0.943	2.056	4.42	<0.005

while still in the green stage (Table III). There was no significant difference; the fast greens did not contain more ascorbic acid. As expected, when fully ripe the fast-ripening ripe halves contained significantly more ascorbic acid than did the slow-ripening halves.

Thus, it appeared that better quality tomatoes (as indicated by higher ascorbc acid content and better external appearance of the ripened fruit) ripened more quickly than did poor quality tomatoes; that, although they contained essentially the same amount of ascorbic acid as the slow-ripening tomatoes initially, they contained significantly more when red ripe. Differences in total soluble solids and total acid content were not significant.

Discussion

Variations in individual tomatoes exist affecting the ripening time and the quality of the ripe tomato. Furthermore, these variations cannot be ascertained subjectively by the appearance of the "mature" green fruit or objectively by the ascorbic acid content of the green tomato. All the tomatoes in the present study were very similar both in external appearance and in their initial content of ascorbic acid. Yet, the tomatoes varied considerably in the length of the ripening period and final content of ascorbic acid. This is contrary to the results of Fryer, *et al.* (6), who found no relationship between ripening time and the final ascorbic acid concentration.

As noted, there was no significant relationship between ripening time and the content of soluble solids or the total acid concentration. The soluble solids did not change at all, but the total acid concentration in the tomato halves underwent a small but general decrease during ripening. The concentrations recorded were similar to those reported by Sando (17). This decrease during the final stages of ripening might be attributed to the utilization of citric and other of the Krebs' cycle acids in respiration (16).

The length of ripening time and the content of ascorbic acid was inversely related. The reasons for this are unknown. The better quality fruit ripens faster than poor quality fruit, although initial ascorbic acid values are similar. One of a number of factors may be responsible. The better quality tomatoes may contain more precursor of ascorbic acid that synthesizes ascorbic acid to a higher final concentration than in the slow-ripening tomatoes. Or, possibly, there is a breakdown of precursor of ascorbic acid in the slow-ripening tomatoes. We did not analyze intermediate stages of ripening; therefore, it is not known whether or not a peak in ascorbic acid was reached with a subsequent falling off.

Ascorbic acid is higher in fruits higher in cluster position on the plant (5) and,

in fruits uppermost on the plant (10). But Fryer, *et al.* (6), found that the stage of maturity does not affect the trend in ascorbic acid concentration with higher cluster position. Thus, they conclude that the causal factor operates prior to the mature green stage. This ties in well with the present findings and points to an explanation based on availability of precursors. Thus, differences in the length of ripening time could be attributed to the original position of the fruit. Precursors translocated into the fruit would be taken up preferentially by fruit in the higher positions. Since light is thought to have influence on ascorbic acid concentration (4, 14) it may, by being more accessible to fruits in higher positions, enhance synthesis of ascorbic acid.

Low ascorbic acid values found in this study, as compared with values reported by Hamner and Maynard (9) and others, have not been explained satisfactorily. Miller and Heilman (12) attributed the low ascorbic acid values in pineapples to injury. This may be part of the explanation. Hamner, Lyon and Hamner (7) found that tomatoes maturing in fall and winter contained approximately half the ascorbic acid content of fruits maturing in summer. The tomatoes used in the present study were grown in fall and winter. Unpublished data from this laboratory shows a seasonal variation in ascorbic acid content.

Summary

We devised a method to assay physiological changes in ripening tomatoes. Analysis of the same fruit in two different stages of maturity served to compensate for individual variability. Each fruit was cut in half; one half was analyzed in the green state, the other half was analyzed after ripening. Faster ripening tomatoes contained significantly more ascorbic acid when ripe than did slower ripening ones. In addition, the results indicate that ascorbic acid increases in the ripening of detached tomatoes.

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Natural Wealth of Tropical American Forests

LLEWELYN WILLIAMS[1]

Introduction

The forest is a vast storehouse of wealth, not only in the form of wood, but also of a wide variety of other commercial materials of major or minor importance. We are apt to regard wood as the sole product of the tree and ignore other products or consider them secondary even though they play an important role in commerce. This is true of temperate forests and is particularly applicable to those of tropical regions. The bullet-tree (*Manilkara bidentata* [A. DC.] A. Chev.) of the Guianas and lower Amazon, for example, furnishes a timber suitable for heavy durable construction, while its bark yields a latex of still greater value as the source of balata utilized in the manufacture of transmission belts, golf-balls, and dentures. In British Guiana, balata extraction has been a foremost industry, for many years classed as the third most important of the country in volume of exports, with approximately 700,000 pounds shipped in 1959, mostly to England.

Like Europe for centuries, the United States has been an importer of tropical forest products since Colonial days. Throughout the years, the consumption of these materials has been tremendous and continues undiminished. Despite the lack of a conservative, rational utilization, tropical forests continue to pour out a great tide of goods essential to the economy of certain nations. Their products may be laticiferous exudates, exemplified by rubber and allied elastomers; soluble gums and resins; essential and other oils; waxes; edible fruits; vegetable ivory; raw sources of fibers, pulp, lignin, and cellulose; and alkaloids for medicinal and insecticidal purposes.

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Amazon Basin—Its Forest Products

A prime example of this natural wealth is the large series of plant products furnished by the rainforests of the Amazon basin. Extending in a broad belt astride the Equator for approximately 3,000 miles from the Atlantic Ocean to the Andean foothills, these rainforests are bisected by the immense Amazon river with its network of tributaries. This maze of large and small rivers sheds a tremendous volume of water draining a territory equal to the United States, excluding California, embracing large sections of the Guianas, Venezuela, Colombia, Ecuador, Peru, and Bolivia, while the Brazilian section alone comprises 40% of the territorial surface of the country (Fig. 1).

Except perhaps in sections of Malaya, Borneo, and central Africa, no other expanse of tropical forests contains such a varied wealth of resources, furnished by several hundred species of tall and medium-sized trees, countless shrubs, vines, and palms.

Timbers. The first tropical American wood to figure in international trade was probably mahogany from the West Indies. Records indicate that West Indian mahogany (*Swietenia mahagoni* Jacq.) was imported into England about 1600 for shipbuilding, and by 1700 had gained a reputation as a cabinetwood *par excellence*. In more recent years, explorations by botanists and foresters have uncovered additional species of true mahogany, including *Swietenia humilis* Zucc. in western Mexico; *S. macrophylla* King in Central America and northern South America; and *S. tessmannii* Harms in the Peruvian Amazon (Fig. 2), where it has

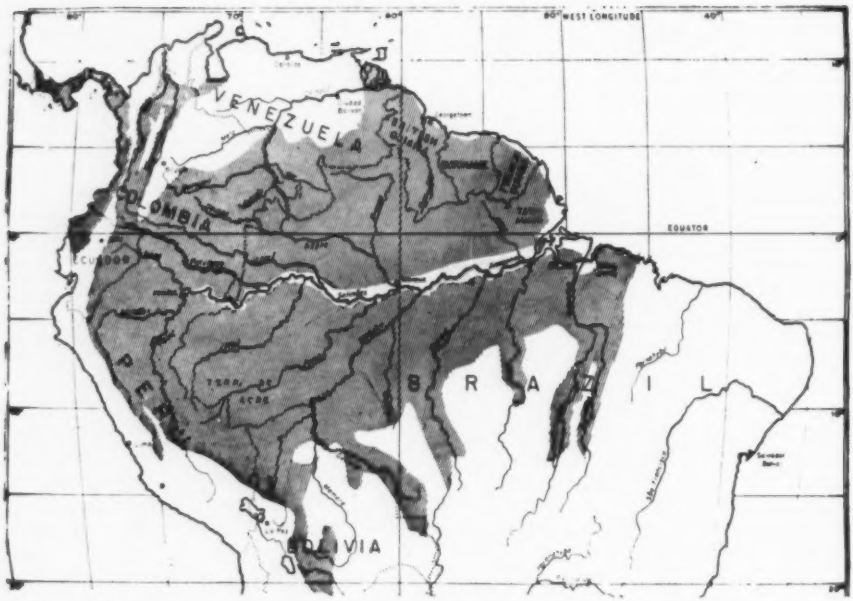

Fig. 1. The range of the Amazon rainforest extends from the Atlantic Ocean to the eastern slopes of the Andes, covering an area more than 3,000 miles long and up to 1,000 miles in width.

Fig. 2. Logs of mahogany (Swietenia tessmanii *Harms) and Spanish cedar* (Cedrela fissilis *Vell.), rafted from the Ucayali basin to the estuary of the Nanay river, below Iquitos.*

been exploited since 1924. But sparsely populated areas, difficult of access, still remain untapped in the headwaters of the large tributaries, particularly those south of the Brazilian Amazon.

Other species of tropical woods have been in use for many decades in the United States and Europe. These include Spanish cedar (*Cedrela odorata* L.) and allied species suitable for fine furniture, interior trim, and in former years used rather extensively for cigar boxes; massaranduba (*Manilkara huberi* Standl.), of the lower Amazon, exported mostly to Europe, but in the United States now found useful in industrial plants and machine shops where strength, durability, and resistance to trucking and other types of hard usage are essential. Brazilian rosewood (*Dalbergia nigra* Allem.), known in commerce for about 300 years, has long been used extensively in this country for cabinet-work and in the manufacture of pianos and fine furniture. New woods from the Amazon and adjoining areas, such as the widely distributed species of *Virola* and *Dialyanthera*, are gradually entering northern markets on an increasing scale as their properties become better known.

While these Amazon forests contain a host of hardwoods of unusual qualities, other lightweight species, such as balsawood (*Ochroma lagopus* Swartz) and setico or imbauba (*Cecropia* spp.), should prove useful as sources of lignin, pulp, and cellulose. One distinctive feature of the Amazon forests, typical of tropical regions in general, is the prevalence of many species within a limited area, but only a relatively few are merchantable, which, so far, has hindered a greater utilization of many of these tropical products.

Rubber and allied gutta gums. Perhaps the greatest contribution made by the forests of the Amazon basin to civilization is the Pará rubber tree (*Hevea brasiliensis* Muell. Arg.). The use of rubber for a wide range of purposes has been known for centuries. It is unnecessary at this time to recount the fascinating history of the rubber industry; that the crude product was known to the Amazon Indian in pre-Columbian times; the contribution made in 1876 by Sir Henry Wickham, who gathered seeds of this tree in the Brazilian Amazon, shipped them directly to England for germination at the Royal Botanic Gardens of Kew, and that these seedlings became the forerunners of the great plantations later established in Malaya, Indonesia, Thailand, and other eastern countries. With the worldwide growth of the automotive age, natural rubber has long been regarded as one of the most coveted forest products of the tropics. By patient and prolonged

Fig. 3. Pará rubber tree (Hevea brasiliensis *Muell. Arg.), showing tapping panels. Tapper is holding a small axe, "machadinha," formerly used to extract the latex, now supplanted by a less injurious gouge (right) to open parallel incisions.*

processes of selection, grafting, and multiplication, the stately Pará rubber or *Hevea* tree, once established in the Far East, has supplied millions of tons of rubber during the past 50 years to meet the world's requirements, upon which this mechanized age has long been so completely dependent. Despite great advances with propagated trees in the Far East, to obtain improved yields, the Acre Territory of northwestern Brazil still remains a source of exceptionally high-yielding "wild" trees, furnishing a rubber of fine quality (Figs. 3 and 4).

In addition to other genera of rubber trees, including the lower grade *Castilla*, *Hancornia*, and *Sapium* rubber, no other expanse of rainforest contains such a variety of latex-yielding trees as the Amazon valley. Despite widespread exploitation over long periods, these forests continue to furnish such exudates of industrial value as balata and massaranduba (*Manilkara bidentata* A. Chev. and *M. huberi* Standl., respectively); sorva or leche-caspi (*Couma macrocarpa* Barb. Rodr.), widely distributed throughout the middle and upper Amazon (Fig. 5); ucuquirana (*Ecclinusa spuria* Ducke); amapá (*Parahancornia amapa* Ducke); the haia-haia (*Lacmellia edulis* Karst.) of British Guiana, Colombia, and Venezuela, and the so-called high and lowland chicle of the Peruvian Amazon, also of the genus *Lacmellia*.

Essential and edible oils. Representative of Amazon trees yielding essential oils, valued in perfumery, is rosewood (*Aniba rosaeodora*, var. *amazonica* Ducke), of the laurel family. The source of this commodity formerly was concentrated in the middle Brazilian Amazon north of Manaus and northeasterly toward French Guiana, but new areas

Fig. 4. A typical rubber camp on the Rio Blanco, Peruvian Amazon. When freshly coagulated, rubber is creamy white, but on oxidation it gradually turns dark brown. Note the fish-net in background, made from the fiber of the young leaves of the Mauritia *palm.*

Fig. 5. "Leche-caspi" or "sorva" (Couma macrocarpa *Barb. Rodr.), frequent and widely distributed in the middle and upper Amazon rainforests.*

have come into production during the last eight or ten years along the Napo, Marañon, Ucayali, and other tributaries of the Peruvian Amazon (Fig. 6).

As elsewhere in tropical America, palms rank among the most majestic and most useful elements in the Amazon forests. Some species form extensive stands, and many play an important part in the local economy, providing readily available materials for sustenance. Of the more than 1,100 species of palms reported to grow in the Western Hemisphere, 440 are to be found in Brazil; Colombia is second with about 200; Peru has 127; Venezuela 88; and so on down the line, with the majority concentrated in the forests of the Amazon valley. Since remote times, the indigenous inhabitants of this region have depended in large measure upon palms and their products for practically all their necessities of life—food, drink,

Fig. 6. Rosewood (Aniba rosaeodora, *var.* amazonica *Ducke). The trunk is cut into short lengths, transported to the river banks, and then shipped to the distilling plants. Middle Napo basin, Peru.*

shelter, clothing, illumination, and fuel. To this day, the Indian fashions from them the requisites of his primitive economy, such as fish nets, hammocks, ropes, mats, poles, blowpipes, rafts and bridges. Brazil is still regarded as the most important source of palm oils in the New World.

Among the oil-yielding palms indigenous to the Amazon may be mentioned the babassú (*Orbignya speciosa* Barb. Rodr.), magnificent palms with elegant feathery leaves, at times forming pure stands of 100 trees to the acre; the burity and murity (*Mauritia vinifera* Mart. and *M. flexuosa* L.); and the bacába (*Oenocarpus bacaba* Mart.), furnishing an oil from the pulp, similar to olive oil. Although some of the oil-bearing palms in the lower basin are known and utilized commercially, the potentialities of extensive stands in the upper reaches of the Amazon still remain almost entirely unstudied.

Waxes. As plant sources of waxes, two Brazilian species of palms, growing in drier areas bordering the southeastern limits of the Amazon basin, play a prominent role in industry. The best known is the fan-leaved carnaúba (*Copernicia cerifera* Mart.) of the arid northeastern region. The United States is the principal buyer of this palm wax, with total annual exports in recent years fluctuating between 19,000,000 pounds, in 1957, and 22,500,000 pounds, in 1959. The other Brazilian source is the ouricurý or licurí (*Syagrus coronata* Becc.), a feather-leaved palm discovered only within the last two decades in the eastern Brazilian states of Pernambuco, Bahia, and Minas Gerais. This palm has a double value, yielding a fine kernel oil as well as an industrial wax. In 1957 total production of this wax amounted to slightly more than 1,000,000 pounds; in 1958, 992,200 pounds; and in 1959, it had decreased to 446,600 pounds. A Colombian feather-leaved palm (*Ceroxylon andicolum* H. & B.) produces, on the trunk, a wax now used mostly as an article of local trade for the manufacture of candles and matches, although formerly, according to Willis, it was the principal source of material for making phonograph records.

Resins and oleoresins. Representative of these products, the widely distributed West Indian locust (*Hymenaea courbaril* L.), of the bean family, has its center of distribution in the Amazon. It furnishes a resin-like gum, known in the trade as South American copal, used for special grades of varnish and to a minor extent for incense and medicinal purposes. The copahiba marimary or copaiba jutahy (*Copaifera reticulata* Ducke) furnishes a thick, yellowish brown balsam, or oleoresin, utilized commercially as an ingredient of medicine and varnishes. The estoraque (*Myroxylon balsamum* Harms), a tall, handsome tree of the Peruvian Amazon, also furnishes an aromatic, translucent oleoresin. A variety of this, (*M. balsamum*, var. *pereirae* Harms), grows mostly along the Pacific Coast throughout Central America as far as southern Mexico, and is the source of Balsam of Peru, an oleoresinous exudation long used medicinally for dressing wounds, in compounding ointments, as well as a fixative in perfumes.

A number of trees and shrubs, growing throughout the Amazon forests, particularly those of the families Anacardiaceae, Euphorbiaceae, Leguminosae, and Sapotaceae, are known to furnish economic quantities of tannin from their bark, fruit, leaves, or wood, but still remain to be investigated. The best known, of course, is the quebracho colorado (*Schinopsis balansae* Engl.), of the sumach family. Although it does not extend into the Amazon forests, this tree is found most abundantly in northern Argentina and as far north as the state of Bahia, in eastern Brazil. Its heavy, durable heartwood contains 30 to 40% of tannin, and 3 to 4% of a soluble non-tannin.

Fig. 7. Splitting the thick-walled, woody, capsular fruit of Brazil-nut tree (Bertholletia excelsa *H.B.K.) to release the seeds.*

Other trees contain alkaloids and glucosides in their bark.

Fruit trees. One of the largest and most famed fruit trees of the Amazon forests is the castanheiro (*Bertholletia excelsa* H.B.K.), long known and of prime importance as the source of the well-known "Brazil-nut" of commerce (Fig. 7). This handsome tree is widely scattered along the middle and upper reaches

of the southern affluents of the Brazilian Amazon, such as the Xingú, and is scattered westward to the Madre de Dios region of southern Peru. Extensive stands of this valuable tree in the remote headwaters of some of these rivers have never been harvested, not only because of difficult access but principally due to the prevalence of hostile Indian nomads. The white kernel of its angular seed contains 60 to 70% oil, composed of elaeine (74%) and stearine (26%), and is suitable as a substitute for olive oil. Used mostly as a confection, the seeds each year form a staple article of export, especially from the Delta region and shipped from Belém. Production of Brazil-nuts in 1960 amounted to 32,000 metric tons, and the 1961 crop is estimated at 35,000 to 40,000 metric tons.

The Tonka-bean tree (*Coumarouna odorata* Aubl.) grows in the upland forests of the states of Pará and Amazonas of the Brazilian Amazon, and is distributed northward into the middle Orinoco basin of southern Venezuela, where it is concentrated mainly along the Caura river. Its seed contains cumarin, a crystalline substance with a peculiar fragrance suggesting vanilla, long used for flavoring tobacco, cocoa, snuff, in confectionery and perfumery, and its oil, known as "cumarú," is used medicinally. Other trees indigenous to these rainforests, as well as many species of palm, yield edible fruits, with a limited local use.

Medicinal and insecticidal plants. The Western Hemisphere, particularly the Amazon basin and adjoining uplands of the Andes, is a major source of important botanicals which have played a notable, in some instances decisive, role in medicine and pharmacy.

The therapeutic value of the cascarilla or quina tree (*Cinchona officinalis* L.), growing in the Andean foothills, has been known since the 17th Century, when an Augustinian monk published in Lima, in 1633, that "there grows in the region of Loja (southwestern Ecuador) a tree called 'fever tree,' . . . the cinnamon-colored bark cures fevers, including tertian."

For more than one hundred years the Andes were the sole source of the cinchona bark. The high prices at which it was sold led to improvidence in the collection of the bark, the trees being felled in great numbers in order to obtain the product. Owing to the lack of a constant and dependable supply to meet increasing world needs, and the realization that continuance of the depredations in collecting the product would result in its extinction, steps were taken in 1859, under the direction of the British government, to establish cinchona trees in the Nilgiri Hills and elsewhere in India. Later the Netherland government cleared large areas in Java and elsewhere in Indonesia for plantations. Immediately prior to World War II the Netherland East Indies produced more than nine-tenths of the world's supply of cinchona bark. This strong position was attained, not only as a result of favorable climatic conditions, but also the systematic and thorough manner with which the industry had been developed. With the outbreak of World War II, resulting in sealing off the supply of this greatly needed commodity from the East, attention was again focussed on the wild trees in the uplands of Colombia, Ecuador, Peru, and Bolivia. In 1942 the United States Government initiated a wartime program of cinchona procurement in these South American countries, involving wide-scale investigations undertaken by a staff of North American botanists and foresters (Econ. Bot. **2**: 229-257. 1948). As a result of these surveys, in 1943 more than 7¾ million pounds of dry cinchona bark were imported into the United States from the four countries mentioned, while during the three years of 1943-45 Peru alone produced more than 4 million pounds.

Another notable medicinal plant in the foothills of the upper Amazon is coca

(*Erythroxylon coca* Lam.), the leaves of which are used for extraction of the narcotic alkaloids cocaine and tropacocaine. This shrub is native to the moist wooded uplands of the Andes. The strength and sustaining power derived from masticating its dried leaves have been known since the reign of the Incas, and this ancient practice is still widely followed throughout the Andean regions.

The seeds of the "guaraná" shrub (*Paullinia cupana* H. B. K.), propagated especially in the Maués region below Manaus, are powdered and roasted to prepare a refreshing beverage, popular throughout Brazil.

Ipecac, from the root and rhizome of *Cephaelis ipecacuanha* A. Rich., of the coffee family, is the source of an alkaloid, emetin, used in the treatment of amoebic dysentery, and is an example of an important drug contributed by the Indians of the Western Hemisphere to present-day medical practice. The product is still obtained mostly from wild sources in the Brazilian forests of Mato Grosso and Minas Gerais.

The bark and roots of a woody vine, known in the Peruvian Amazon as cunshu-huayo (*Chondodendron toxicoferum* Krukoff & Moldenke), furnishes curare. Long applied by the Indian to his darts for hunting, and considered among the deadliest of poisons, this extract is utilized in the treatment of spastic paralysis, and especially as a special anaesthetic in delicate heart operations.

Approximately 1,200 different species of plants are reputed to contain alkaloids toxic to insects, and the majority of these are of tropical origin. The most important in the Amazon basin is *Lonchocarpus nicou* D. C. of the bean family, variously known locally as "barbasco," "timbo," "cubé," or "haiari" (Fig. 8). Cubé roots have been used since time immemorial by the Indians of the forest regions of the Amazon, Orinoco, and elsewhere in northern South America, as a potent fish poison, but their insecticidal properties became known only about three decades ago. Containing from 3 to 12% of the alkaloid rotenone, these roots serve as a base in the manufacture of an insecticide, as a contact and stomach poison. When the supply of pyrethrum powder from central Africa and Ceylon was disrupted during World War II, cubé roots propagated in the Peruvian Amazon, especially along the Huallaga and Marañon rivers, became the primary source of this important commodity, with an annual production of several thousand tons.

The list of useful by-products of these vast Amazon rain-forests could go on indefinitely.

Transportation

Until recent years few all-weather highways existed within the length and breadth of the Amazon valley. In most cases these were or still are second or third class roads, trafficable only during the dry season, and confined to short stretches within the environs of the larger centers. Likewise, there are only two or three railroads, with outmoded equipment, namely that operated from Belém through Bragança, in the state of Pará, and the now little-used Madeira-Mamoré railroad, built during the period when the Amazon forests were the principal source of Pará rubber. Several plans have long been under consideration to prolong the Lima-Cerro de Pasco railroad to the upper Ucayali river, but the project has never been completed.

Despite the serious lack of land communications, the vast fluvial network has facilitated greatly the penetration of this vast region, even to the most remote areas, and made possible the maintenance of trade between the three most important collecting and distributing centers, situated on the Amazon river, and the outside world. Ocean-going vessels up to 10,000 tons are able to reach Manaus, 1,000

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*Fig. 8. Roots of a scandent shrub, "barbasco" or "cubé" (*Lonchocarpus nicou *(Aubl.) DC.), a source of rotenone, an alkaloid used as a base in the manufacture of insecticide. Huacachina, upper Marañon, Peruvian Amazon.*

miles inland, throughout the year, while those with a displacement of 4,000 or 5,000 tons continue to Iquitos, in Peruvian territory, 2,400 miles up the main stream. In addition, a large number of government-owned or privately operated

river steamers and launches ply constantly between Belém, Manaus, Iquitos, and the many communities along the Amazon and its many large and small affluents.

The first flight over the Peruvian Andes was accomplished in 1928, from Lima to Iquitos. Since that time the Faucett Airline of Peru has gradually expanded its operations, so that today they cover most of the country, including a frequent, scheduled service between Lima and the Peruvian Amazon, with airports at Iquitos, Yurimaguas, and Pucallpa. Panair do Brasil for several years has maintained a weekly round-trip flight between Belém, Manaus, and Iquitos. This and other Brazilian airlines also operate daily flights, linking Belém and Manaus with the capital, and such coastal centers as Salvador, Santos, and São Paulo.

Considerable progress has been made during the last decade or so in constructing new highways, or in improving the few existing ones, which should lead to an improvement of internal trade between the coastal cities and areas situated in the deep fastnesses of the rainforest and hitherto considered inaccessible.

Soon after World War II the trans-Andean highway from Lima to Huanuco was extended to Pucallpa, on the upper Ucayali. This has resulted in increased traffic along this route, since increasing volume of products originating in the Peruvian Amazon, formerly exported from Iquitos and shipped down the Amazon, are now transported in river steamers or on barges along the Ucayali river to Pucallpa, thence by truck over the tortuous 500-mile highway to Lima and Callao (Fig. 9). Farther north construction is nearing completion of an all-weather inter-Andean highway from Chachapoyas through Cajamarca to Pacasmayo.

In the Brazilian Amazon two important

Fig. 9. A section of the trans-Andean highway in Peru approaching Pucallpa, upper Ucayali.

and extensive highways are under construction. One of these leads southward from Belém to the new capital, Brasilia, in the state of Goias. The other links Cuiabá, capital of Mato Grosso, with Pôrto Velho, Rondonia territory (formerly territory of Guaporé). It is anticipated that this highway will eventually connect with the Peruvian trans-Andean highway from Lima to Pucallpa.

Prospects

Up to the present many factors have retarded the progress of the Amazon valley. As already pointed out, in Peru, for example, the lack of a system of roadways has hampered internal trade between coastal cities and remote areas east of the Andes. Perhaps the foremost factor throughout the years has been the inadequate supply of labor, and despite efforts made by the Brazilian and Peruvian governments in recent years this problem still remains to be remedied. During the past 30 or 40 years Brazil has encouraged and aided migrants from other countries, particularly Japan, to establish colonies in sites along the Amazon, between Belém and Manaus, and in the newly created territory of Amapá, where they are dedicated to the growing of pepper and jute. Unfortunately, the majority of the original settlers moved southward, to areas where the soil is considered more fertile, the climate more agreeable, and today the Japanese colony in the state of São Paulo numbers more than 300,000. During World War II many families moved from the arid region of northeastern Brazil to the Amazon valley, but after the termination of hostilities most of these families returned to their original homeland. Similar attempts were made by the Peruvian government during the early part of this century to establish European and Japanese colonies in the Chanchamayo valley and elsewhere in the Andean foothills.

Need of Surveys

The primary and secondary products of temperate forests of North America and Europe have been thoroughly classified and studied over the years, leading to a better appreciation and a more intensive utilization of their natural wealth. While certain areas of the Amazon forests have been studied and authentic collections made by a limited number of botanists and foresters over the past 30 or 40 years, supplemented by surveys made by forestry missions, sponsored by FAO, mostly in the lower reaches of the Brazilian Amazon during the last 10 years, systematic investigations still remain to be made of large sections of these rainforests, especially around the headwaters of many of the large tributaries. We still lack knowledge on the occurrence, distribution, and density of even some of the more important or frequent trees furnishing useful timbers, gums, or resins. This information is essential to create a domestic and foreign market for these varied products, and to attract capital for the development of forest industries. The key to the solution of this problem lies in continued and expanded scientific exploration and research. The most important individual in an undertaking of this nature is the scientist, who can determine the qualities and potential uses of primary or secondary products of different species, and who by intensive investigation is able to ascertain the location of these resources, their yield, character, problems of logistics, and other factors influencing their utilization. This work involves coordination both in field investigations and laboratory research between nations in a common problem. Progress in this direction is gradually being acomplished by the forestry missions supported by FAO, which have carried out special surveys in recent years in the state of Pará and the territory of Amapá, lower Amazon.

A program aimed at the study and

eventual utilization of forest products of tropical origin, such as those of the Amazon valley, involves several phases:

Field investigations—to assemble authentic material for study, accompanied by vital information regarding the location, distribution, and extent of various species, forest types, labor supply, accessibility, and other factors related to their utilization and conservation.

Economics—concentrating on industrial needs and the adaptability of the various products to these requirements.

Laboratory research—of a fundamental nature, including the botanical classificiation of materials, to clarify the confusion often resulting from the multiplicity of vernacular names; physical, mechanical, and chemical tests to correlate other lines of investigations; and the dissemination of information through reports and publications based on field observations and results obtained in the laboratory.

Cooperation—contributing to the coordination of activities by establishing relations between forest departments in tropical areas, forestry missions, and research institutions in temperate countries.

Outlook

Up to 40 or 50 years ago tropical forests were regarded mainly as sources of fancy or unusual woods suitable for specialty purposes, or of such products as rubber, gums, resins, or essential oils available only in those regions. Since World War I a great number of woods originating in the Amazon basin have been studied, the qualities of many have become better known, and some of these are now used on an increasing scale both locally and in forest industries of the United States and Europe. Likewise, new sources of essential oils, gums, and other secondary products have been discovered in recent years to supplement supplies from other countries.

With a rapidly expanding world population it is realized that the forests of North America and Europe are not inexhaustible, while the demand for natural products continues undiminished. The time is approaching when it will become necessary to utilize hardwoods and other forest products of tropical origin, on a still larger and more diversified scale to supplement the resources of temperate zones.

Some evident, although slow, improvement has been made during the last 20 or 30 years in the economic conditions prevailing in some areas of the Amazon valley. Commercial centers, such as Iquitos, can now be reached by air in a matter or 3 or 4 hours from Lima, compared with upwards of 3 weeks over the land route in former years. The logging of mahogany and Spanish cedar has continued without interruption since 1930 along the Ucayali, Javarý, and other rivers, and several sawmills are in constant operation near Iquitos, Manaus, and Belém. Plantations of jute and pepper have been established in the lower Amazon, and the area of *Hevea* plantings is being increased in the state of Pará. A jute mill has been in operation for several years in Manaus, and several plants to distill rosewood oil or to process natural gums have been built in Iquitos.

But a greater utilization of the forest resources, especially in the more remote areas, is still retarded by problems which await solution. The improvement and extension of existing roadways, the completion of highways now under construction through some of the isolated zones of Brazil, and the application of modern equipment will play an important part in their economic development. In return the natural riches of these hitherto little-known, latent areas will become increasingly available to the countries directly involved, as well as to other nations interested in the utilization of their products.

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Economic Botany as an Advanced Science Course in Secondary Schools[1]

GEORGE UHE, JR.[2]

During the past decade, many secondary schools have been revising their science curriculum. Some schools are stressing the physical sciences in keeping, they believe, with our country's recent entry into the "space age." Other schools are merely altering their program to offer more challenging subject matter to their above-average and gifted students. Besides such conventional science courses as general science, biology, physics, and chemistry, new subjects have been suggested that could be added to the curriculum: geology, astronomy, meteorology, and hygiene. Many schools offer two years of chemistry and two years of physics in the senior high school and even a second year of biology.

I do not wish to delve into the pros or cons of any of these subjects or programs. I wish, however, to give my reasons for supporting economic botany as a secondary school subject and tell something about what we did in this regard at the school where I have recently taught.

For the past three years, until June, 1961, I taught science in the junior high grades at Renbrook School in West Hartford, Connecticut. My major interest in science is economic botany, and I have felt for many years that there is a place for this subject in the secondary school science program. Ideally, I believe it would be most advantageous for the student to take economic botany as a second year of biology in the eleventh or twelfth grade. However, the subject matter can be adjusted for junior high school grades, if we consider the advanced sections only. At the present time economic botany is a college course usually taught in the third or fourth year. I do not know of any secondary school, other than Renbrook, where it has ever been offered.

Why teach economic botany at the secondary level? What does this subject have to offer that specially recommends it for this level of teaching? The reasons can be summarized as follows:

1. The content of this course fits the immediate needs of the student's curiosity of the plant world about him.
2. The student obtains a greater sense of appreciation for his botanical environment. This new knowledge and awareness gives the student new dimensions to explore, not only in his own community but when traveling away from home.
3. Economic botany deals with materials very familiar to the student though he has little knowledge about these materials.
4. The appreciation for the plant kingdom and its importance to mankind obtained in this course will help "sell" botany, a subject often looked upon with distaste in high school and college by young students.
5. Alcohol, tobacco, narcotics and caffeine beverages can be discussed from a neutral, scientific point of view. Knowledge in this area is important for young people who will soon, if not already, experiment with many of these plant products. It is far better to

[1]Presented at annual meeting of The Society for Economic Botany, 13 May 1961.

[2]Present address: Pago Pago, American Samoa.

approach such topics unemotionally as a regular part of the science course than to make something special of them.

6. The brief introduction to systematic botany acquaints the student with the need for orderliness in science

7. This course correlates with geography and Latin, which these students would be taking at the same time or have just recently taken.

The reasons I have just outlined are unique, I feel, to economic botany.

When I was asked to plan a three-year science program for the new upper division of Renbrook School in September, 1958, I decided to offer economic botany in the seventh grade, general science in the eighth, and general biology in the ninth. This program would only include the advanced sections. The regular sections would follow the usual junior high science program.

I devoted the last quarter of the 1958-59 school year to economic botany for all sections of the seventh and eighth grades. I wanted to see how the students received and handled the material. The subject matter consisted of a brief introduction to the plant kingdom, systematic botany, and the food plants. The only text material used was a twelve-page pamphlet I prepared specially for the students on the plant kingdom and taxonomy. The material was greeted with enthusiasm. I did feel, however, that the parts dealing with the plant kingdom and taxonomy, as expected, were too difficult for the regular sections.

During the school year of 1959-60 only the upper two sections of the seventh grade took economic botany. The classes met three periods a week, one double and one single period. We used the booklet that I prepared the year before on the plant kingdom and taxonomy and *The Story of Plants* by John Hutchinson and Ronald Melville. The latter is a British textbook, well written and attractively illustrated. The school had an unusually good source of reference material. From our science library shelves the students had access to many of the general reference books in the field of economic botany as well as many of the more specialized books dealing with food plants, drugs, spices, etc. In addition to these references, we started a picture and magazine file.

At the end of the second quarter, we decided that the textbook was too difficult for the students in the upper, regular section. However, the advanced section continued to use the text for the remainder of the year.

During the year, in addition to a brief introduction to the plant kingdom and plant taxonomy, the class covered such areas as plants and ancient man, food plants, beverages, drugs, fumitories, spices, essential oils and textile fibers. The origin of plants and how and why they traveled to other parts of the world was particularly stressed. Latin names for plants were not emphasized unless they were meaningful for the student in better understanding the plant or could be correlated with his elementary knowledge of Latin. *Theobroma cacao* would be an excellent example of the former. The genus name, *Theobroma,* comes from Greek and means food of the gods. *Cacao* is the aboriginal name for the plant, an excellent name for the chocolate tree. *Piper nigrum* (black pepper) and *Betula alba* (white birch) are good examples of plant names using simple Latin.

A term paper was required of each student on some plant product. A number of the papers were of exceptional quality. The results with the regular section were disappointing. The material presented would have to be markedly simplified in order for the students to have any degree of success. Since the subject matter could stand just so much simplification, without teaching pure economic

geography, it was decided to give economic botany only to the advanced section the following year.

During the 1960-61 school year the classes met four periods each week, one double and two single. The course started in September with the collection and use of local wild plants. This was a substitution for the section dealing with plants and ancient man. We used the same textbooks as the year before and, in addition, we used Nelson Coon's *Using Wayside Plants*. This section on wild plants was followed by an introduction to the plant kingdom and basic plant taxonomy. This was followed by food plants, beverages, drugs, fumitories, spices, essential oils, fibers, gums and resins. I did not require a long term paper this year, but a number of short papers instead. Some of the students, in all the science sections, submitted economic botany science projects in the school science fair. For example: beer and wine making, alcohol distillation, perfume making, distillation of flavor oils, and paper making, to name a few. Again I felt that the course had been successful. The material interested the students, was not too diffcult, yet offered a challenge.

There is no end to what can be accomplished in the laboratory in a course of this nature. If the teacher is alert, all sorts of materials can be collected from his own community. The students are also eager to contribute items, obtained from vacation trips, to the general laboratory collection. In this respect, I have found them an excellent source. Through the kindness of Dr. Richard Evans Schultes, Curator of the Botanical Museum of Harvard University, we were able to enjoy a few, not easily obtainable, tropical items. During the past three years we distilled alcohol from both homemade wine and cooking sherry, distilled the oil from eucalyptus, peppermint and bay-rum leaves, made dye from poke berries, boiled down maple sap, made snuff, made paper, and roasted and ground chicory roots. The students sampled such things as chicory, moxie, maté, sugar cane, corn syrup, blackstrap molasses, soybean cookies, cassava bread, tortillas, piñon nuts, St. John's bread, sorrel, dandelion greens, wild grapes and hickory nuts, spruce gum, raw chocolate, and raw sugar. We examined and studied crude and refined spices, cereal grains, samples of essential oils, various resins, wood samples, fiber samples, cocoa pods and beans, and several patent medicines containing plant ingredients.

The overall reaction to economic botany on the part of the students has been singularly favorable. The only adverse comments were by some of the boys who felt that science should consist of electricity and rockets, and had to be sold on undramatic plants. This is an expected reaction at this age level. The most favorable comments came from students who had been fortunate enough to travel during the spring and summer holidays. They visited such places as cane fields and sugar mills in the Virgin Islands, a citrus processing plant in Florida and flower fields and perfumeries in southern France. These visits, they confided, were the result of the interest obtained from the course. The reactions from some of the other faculty members were equally favorable. The geography teacher was especially pleased with the way our two subjects correlated.

I, personally, was very pleased with the way the course ran, except for three things. First, the textbook, *The Story of Plants* by Melville and Hutchinson, though attractively illustrated and interestingly written, is not a very useful textbook and would be better for outside reading. A suitable textbook for the seventh grade presents a problem. For the eleventh or twelfth grades, Hill's *Economic Botany* or Schery's *Plants for Man* would be quite suitable. Secondly, I did not make full use of field trips. There are always industries to be found, not

far from a school, that use raw materials from plants. Hartford is no exception. I regret that we did not get to the Fuller Brush Factory, where plant fibers from all over the world are made into a variety of brushes and brooms. We did make a trip, however, to see how tobacco leaves, for cigar wrappers, were graded, cured and packed for shipment. Thirdly, I made little use of motion pictures. There are numerous excellent films available from a variety of sources. Most of these are loaned without charge.

I believe that not only did this course in economic botany fulfill the purposes outlined in the beginning of this paper, but met the general requirements of any good science course. It taught the students to explore with all their senses and to do this exploring in some orderly fashion, with a purpose in mind and conclusions to be drawn. It would be better, without a doubt, to teach economic botany as a second year biology course, as an elementary knowledge of biology would be advantageous. But even as the first formal science course the student takes, economic botany is exceptionally rewarding.

I hope this course, or at least some of its content, will continue to be taught at Renbrook School. I would strongly urge any teacher who is so inclined and has the necessary botanical background, to try economic botany as a special science course in an advanced program in the junior or senior high school.

Problems in the Compilation of a Native Medicinal Flora of Southeastern Asia[1]

LILY M. PERRY[2]

My assistants and I have been assembling material for a native medicinal flora of Southeastern Asia. It occurred to us that some of the problems we have encountered in this work might be of general interest. By way of historical review it is well known that among natives of various countries a knowledge of these medicinal uses has been passed by word of mouth from one generation to another of priest doctors, witch doctors or medicine men. From their practice many legends of magic and medical lore have developed. But the first authentic written record is the herbal attributed to Hippocrates in 466 B.C. It contains an account of some 400 herbs of healing value, some of which are still in use (poppy, castor bean, henbane, mints, pennyroyals, and others).

Even to this day in some countries (*e.g.* China) a native first consults the herbalist, then if necessary, the man of modern training, the physician. The origin of the knowledge of Chinese medicine also belongs to ancient legends. It is said that the first Chinese herbalist was the Emperor Shen Nung (2800 B.C.), who studied the effects of herbs on the human body and recorded his results in the Shen Nung *Pen Ts'ao Ching*. Just when it was published is not known but some believe that it was not before the Han Dynasty (206 B.C.-220 A.D.), during which time was the Golden Age of Medicine in China. This work is considered not only the most ancient Chinese *materia medica* but is the foundation of later works on the subject (*7*, 11, 16).

In the Tang and Sung dynasties it became common practice for the Emperor to command the court physicians to compile or revise the *materia medica*, making the revision the official guide in medicine. These works culminated in the *Pen Ts'ao Kang Mu* (a work of 52 volumes) by Li Shih-chen in the latter part of the sixteenth century. This work is still the accepted standard for Chinese doctors today. Progress made after that time was kept secret for the advantage of the discoverer, or only passed on to his sons; this was true until the advent of modern medicine.

Down through the centuries the greater herbals gave rise to the pharmacopeias. Although the pharmacist was always trying to discover from the extract of the plant the reason for its healing power, it was not until the early part of the 19th century that much progress was made. Then the isolation of morphine, quinine, caffeine, and other alkaloids followed in quick succession. At the same time efforts were undertaken to synthesize drugs. This was the beginning of the trade of the manufacturing pharmacists in the drug industry. Working with organic chemicals of plants, they found many drugs in common use did not seem to have any basis for their reputed action and these were dropped, but the search continued for others. Some of the synthesized drugs were not so effective as the natural ones. The result has been a growing medical and commercial interest in evaluating medicines in the light of modern science.

The literature of folk medicine is rather scattered and the records of medicinal

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[1]Presented at annual meeting of The Society for Economic Botany, 13 May 1961.

[2]Arnold Arboretum, 22 Divinity Avenue, Cambridge 38, Mass.

plants often are included with those of other economic value. We believed that if we could assemble a native medicinal flora of Southeastern Asia by listing the uses of various plants from the different geographic areas of the region, it might be possible to find a pattern of consistency in their uses and bring to light the more important medical ones.

It has not been easy to set the limits of the territory that we could cover. Geographic boundaries do not necessarily indicate the natural range of species. However, the Eastern Pacific area is one of overlapping ranges and often closely related species; so we decided to include material from Burma, Thailand, Indo-China i.e., Laos, Cambodia, Vietnam, some work from China and Japan, Malaya, Indonesia, the Philippines, and whatever we can learn from New Guinea and the Solomon Islands. This area and the plants from it are traditionally an interest of the staff of the Arnold Arboretum. The herbarium, the library, and our records contain much information from there. We are now collecting data from any available source and if anyone would like to offer help or suggestions we shall be grateful. Our card catalogue now contains records of the medicinal use of plants from about 35 families of ferns and fern-allies with some 55 genera. In the flowering plants we have records of medicinal uses in 204 families with some 1400 genera. The largest family is Leguminosae with 95 genera, Compositae with 70, Rubiaceae, Euphorbiaceae, and Orchidaceae with some 50 genera each, eleven families with 20-30 genera; the others are smaller but not necessarily less important.

We have gathered this information from herbarium specimens, collectors' field notes, travellers' reports, people in the territory and published literature. Of necessity, the value varies both with the worker and the difficulty in obtaining accurate information. One such hindrance which western people encounter is their lack of understanding of the native's language. When a collector asks the name of a plant, the native reply may only be the equivalent of "I don't know," but the collector assumes it is the name of the plant. Or if he asks information concerning its uses, the native may or may not know or may wish to conceal the fact that he doesn't know or even conceal its use and gives a misleading answer. Explorers do not always find it easy to learn the customs of a strange people. I have been informed by a mutual friend that Captain Kingdon-Ward, an eminent collector and traveller in Burma and Tibet, indicated that there were natives who seemed well versed in the use of healing plants, but they were very loath to part with their information. It was as if this knowledge were private property and others had no right to intrude. In one of Captain Kingdon-Ward's books on Burma (8) he says, "There are almost certainly drugs, known to the hill people, of which we know nothing." Or if a collector learned a name, how could he be sure it was for the plant to which the use was given; it might only be a nearly related one. Again, the same native name may be applied to more than one species; it may only indicate some similarity between plants. For example, the Javanese word "pranadjiva" is the name used in the medicinal trade for the seeds of two very different plants, *Euchresta horsfieldii* Benn. of the Leguminosae and *Sterculia javanica* R. Br. belonging to the Sterculiaceae. The seeds so closely resemble each other except for flavor, says Heyne (5) that the natives believed that the properties of the two are similar. The seeds of *Euchresta* are very bitter and contain a poisonous alkaloid; they are a renowned remedy for chest complaints, but Mrs. van Steenis (14) doubts whether their reputation as a cure for consumption can be maintained. The *Sterculia* seeds are not bitter, contain very little alkaloid and are relatively harmless in comparison to those of *Eu-*

chresta. Other examples may be found in Vidal (15) or Burkill (2).

Again one cannot be sure of the identification of the plants mentioned in travellers' reports. Even in scientific articles contradictions are found. Chaulmoogra oil was used for many years in the treatment of leprosy. In 1899 a French pharmacist, G. Desprez (1, 3, 4) discovered that the seeds from which the oil was obtained were not those of *Gynocardia odorata* R. Br. but of another plant. The English, on learning of this, alerted Sir George Watt (12), and he "sent specimens to Col. Prain (Sir David Prain) who, in a letter dated June 28, 1900, write, 'Your 14421 from Chittagong is a great find. These are the real chaulmoogra seeds of the Calcutta bazaar and of the Paris and London drug dealers. It certainly is not a *Gynocardia*. I believe it is a *Hydnocarpus* and so now do my friends in Paris. . . .'" Another item quoted from Hooper (6): "In April, 1901, Colonel Prain on being supplied with material, recognized the plant as *Taraktogenos kurzii*, a species described by Sir George King in 1890."

Subsequently much work was done in the 20's and since, both as to the sources and the analysis of the oil. It has been found in varying quantities in several species of *Hydnocarpus*, but none in *Gynocardia*. In fact, when Sleumer (13) in 1938 published a monograph of *Hydnocarpus* including at the end a key to the species used pharmaceutically, he also added a note on some genera with little or no medicinal value, including *Gynocardia*. Yet in 1954, Alfred Mosig (9) in an article on some important drug-plants in Chinese medicine indicated that the seeds of *Gynocardia odorata* produce Chaulmoogra oil; later in 1958 (10) he called the oil "fake" Chaulmoogra oil and indicated its use for leprosy. Now the geographic range of both *Hydnocarpus kurzii* Warb. and *Gynocardia odorata* R. Br. is in Burma, and the Chinese imported the seeds used for leprosy so it seems logical to accept this as a mistaken identity, perhaps carried over from the old literature, although it doesn't seem as if all the work done on Chaulmoogra oil in the intervening years would be so easily overlooked.

In closing, we would point out that there are species covering the whole area which have manifold uses in all the region. Such a one is *Alstonia scholaris* R. Br. of the Apocynacae, known by a wide variety of native names. It is used as a tonic, astringent, febrifuge, vermifuge, dysenteric, general vulnerary, and for several local uses. In contrast, some species with the same wide range have limited use. An example of this would be the seeds of *Cucurbita moschata* Duchesne, the musk melon. From China to Palau in the Caroline Islands the seeds of this are used as a vermifuge for intestinal parasitic worms. It is a specific for tapeworm. A third category might be mentioned in which species have a limited range although the genus is widespread. Different species may have the same use in different geographic areas, but many uses appear to be unrelated. Take the genus *Psychotria* which has a wide variety of species, also medicinal uses, but of these only a few uses are attributed to a single species.

In the coming year we hope to have this material assembled for publication. We do not know whether the work will show many plants with similar uses over the area, or whether those plants which have the same use will contain only the better known drugs. Wherever the constituents are readily available we plan to include them. We believe that these will make the work more valuable to medical investigators and pharmacists in their search for new or improved curatives.

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A Statistical Study of Relationships of Certain Species of the Solanum Nigrum Complex[1]

JORGE SORIA V. and CHARLES B. HEISER, JR.[2]

Introduction

The black nightshades, *Solanum nigrum* and related species, although primarily known as poisonous plants, have served as minor food plants in many parts of the world. The plants have been used as potherbs and the berries have been used for the preparation of preserves and pies. The introduction of one species, the "sunberry" or "wonderberry," supposedly of hybrid origin, as a food item by Luther Burbank at the beginning of the century, produced a notable controversy that did much to bring Burbank's work into disrepute. One species, the "garden huckleberry," *Solanum melanocerasum*, is still offered by some seed companies for table use. At present, the Solanum alkaloids are under intensive investigation by Dr. L. H. Briggs and his group at the University of Auckland in New Zealand. Perhaps the nightshades' greatest claim to fame, however, lies in the fact that *Solanum nigrum* was used for the production of the first artificial polyploid (Winkler, 1916). Other sections of the genus contain some extremely important economic plants, the Irish potato being chief among them. The purpose of this paper, however, is not to discuss the economic aspects of the genus but to present a procedure for studying species similarity by a statistical method. This method, while of general application to taxonomic work, seems to offer particular promise in the study of complex problems, such as are typified by any of our important cultigens.

The section *Morella* of the genus *Solanum* comprises a large number of very similar species of wide distribution with the greatest concentration of species in the tropics. Dunal in de Candolle's Prodromus in 1852 reported 52 species in the section *Morella vera*, and Bitter, from 1910 through 1917, added nearly 100 more, many of doubtful validity. A few cytogenetic studies of certain species of the complex have been published, among them being those of Jorgensen (1928) for certain European species, Stebbins and Paddock (1949) for the Pacific coast of North America, and Heiser (1955) for Costa Rica.

The present work was undertaken in an attempt to arrive at a better understanding of certain tropical species of the complex and to test certain statistical procedures for determining relationships.

[1]Both authors would like to express their appreciation to the John Simon Guggenheim Memorial Foundation. The senior author carried out the statistical and cytogenetic analysis while at Indiana University on a Guggenheim Fellowship, and the junior author collected much of the material for the study while a Guggenheim Fellow in 1953. The authors would also like to express their thanks to those mentioned in the paper and others who furnished seeds or herbarium specimens for study. A key to the species in the present study and their detailed descriptions as well as much of the details concerning the statistical and cytogenetic analysis may be found in the senior author's Ph.D. thesis (1958) in the Library of Indiana University. The thesis is available on microfilm from University Microfilms, Ann Arbor, Michigan.

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It would have been highly desirable to have included all of the species of the section for the latter study, but in view of the large number of species and the difficulty of securing seeds of certain tropical species, this was not possible.

Materials and Methods

Nineteen populations of 20 plants each belonging to eleven different species were grown in the greenhouse of Indiana University for the present work (Table I), seventeen of which were analyzed in detail. Smaller populations of these species from other sources were also grown for observation but not included in the detailed study. Herbarium material from Indiana University, the Missouri Botanical Garden, and the United States National Museum was consulted during the study. Voucher specimens for all the species and hybrids grown for this study are deposited in the herbarium of Indiana University.

Morphology is the principal tool of taxonomists. Study and comparison of characters is the usual procedure to separate species from one another and to determine relationships of species. Some subjective judgment may prevail in this procedure because of the selection of certain characters over others. In order to avoid personal opinion as much as possible, some mechanical procedure based on data from the greatest number of characters possible would be desirable. Anderson (1954, 1956), in particular, has proposed many useful theoretical statistical devices to solve problems of classifications of populations, but the multiple character analysis of higher plants, based on numerical data as a criterion for separating species and indicating relationships has been little used. Working with bees, Michener and Sokal (1957) and Sokal and Michener (1958) presented such a method and demonstrated the applicability of statistical procedure to judge taxonomic relationships. Morishima and Oka (1960) applied this method to the study of rice species, and Rogers and Tanimoto (1960) have suggested a somewhat simplified method adapted for computer use.

The method proposed by Sokal and Michener is based on the fact that if a group of species has originated from a common ancestor, the more closely related ones will have the most characters in common. By estimating their similarity by correlation coefficients, one will find the highest values for those species morphologically more similar, and these coefficient values will decrease with more distinctly related species. Michener and Sokal emphasize that measurements have to be obtained of the greatest number of characters possible in order to have an adequate sample of the genetic compositions of the species. The use of a small number of characters might give a false impression in that the correlation figures could be strongly influenced by convergent evolution in certain characters of species which are not actualiy closely related.

The senior author envisioned a statistical approach to the problem of relationships in *Solanum* in 1956, and with the appearance of the work of Michener and Sokal it was decided to adopt their basic method since the general principle was identical. The product moment-correlation coefficient was used to correlate species with each other. After securing the correlation coefficients, a process of grouping was begun. A nucleus of a group of related species was determined by using the two species with the highest average correlation coefficients. The next species added to the group was the one having the highest correlation with the members of the group previously determined. The limit of the group is determined by decreases based on the average correlation ($\overline{Ln}$). A significant drop of coefficient was empirically determined using the

TABLE I

SOURCE AND CHROMOSOME NUMBERS OF SPECIES OF *Solanum* USED IN PRESENT STUDY.

Species and Accession Number		Chromosome Number	Source	Collector	Distribution
S. americanum Mill.	S116	12	Posey Co., Ind.	C. B. Heiser	Eastern U. S.
	S117	12	Ingram Co., Mich.	C. B. Heiser	
	S118	12	Highlands Co., Fla.	W. P. Stoutamire	
S. amethystinum (Kuntze) Heiser	S106	12	Carpintera, Costa Rica	C. B. Heiser	Highland Central America
S Douglasii Dun.	S140	12	Bernalillo Co., N. M.	R. C. Jackson	Western North America
	S143		Santa Barbara Co., Calif.	Katherine Muller	
S. gracile Dun.	S144	12	Westland, New Zealand	G. T. S. Baylis	South American, intro. weed in Southeastern U. S. and New Zealand
S. interandinum Bitter	S129	24*	Patate, Ecuador	J. Soria	Highland Ecuador
S. Leonii Heiser	S109	12*, 24	Poas, Costa Rica	C. B. Heiser	Highland Costa Rica
S. melanocerasum All.[1]	S132	36		C. A. Jorgensen	Unknown (Bitter, 1913)
S. nigrum L.	S133	12	Denmark	C. A. Jorgensen	Europe; now a cosmopolitan weed
S. nodiflorum Jacq.	S102	12	El Tejar, Costa Rica	C. B. Heiser	Cosmopolitan tropical weed, mainly America
	S103	12	San José, Costa Rica	C. B. Heiser	
	S122	12	Nana, Peru	C. Rick	
	S127	12	Karad, India	Anand Sawant	
	S128	12	Pichilingue, Ecuador	Jorge Soria	
	S151	12	Medellin, Colombia	Hno. Daniel	
S. Roxburghii Dun.	S126	24*	Karad, India	Anand Sawant	India
S. villosum Dun.	S135	24	Denmark	C. A. Jorgensen	Europe, Arabia, intro. weed in U. S.
	S136	24	Denmark	C. A. Jorgensen	

*Counts reported for the first time.

[1]This species which has long gone under the name *S. guineense* Lam. was described as *S. intrusum* Soria in an earlier paper (Soria and Heiser, 1959). Dr. K. J. W. Jensen of Holland in a letter of October 12, 1959, to the junior author pointed out that an earlier name, *S. melanocerasum*, was available for this species, and later this was pointed out in print by Heine (1960).

technique of Holzinger and Harman (1941). In the Michener-Sokal study, where 60 characters were used, a drop of 0.030 was adopted; in the present study, where only 26 characters were employed, by empirical trials 0.040 was adopted as drop value because of the larger error resulting from using fewer characters.

Choice of Characters and Scoring Method. Since we were dealing with a group of closely related species, 26 characters was the maximum number which we could obtain for this study. Units of measurement varied with the nature of the character, arbitrary scoring being done where direct measurement was impractical. The numerical data were then converted to standard units in order to have adequate comparisons. All the values for the characters under study were based on 22 samples taken from the main stems of 10 plants of each taxon. The characters selected and the maximum value assigned to each are presented in Table II. Those characters marked with an asterisk were scored, and direct measurements were used for the others.

The character of a species with the highest numerical value was made equivalent to a value of 10 or less units; proportionally, the values of the characters in other species were reduced to this scale. For example, the maximum pollen grain diameter for any species was 27 micra (*Solanum nigrum* L.); therefore, a pollen grain of 17 micra will have a value of 6.2 units. For a few less conspicuous characters or where accurate estimates were difficult to obtain, a value of less than 10 was given to the character in the species with maximum expression, and the equivalents for the others were proportionally determined. This procedure results in the weighting of characters. However, because of the small number of characters considered in this work, when the ideal would be over 50, some weighting seemed to be necessary. This, of course, introduces a subjective element, and "taxonomic judgment" was used to select those characters which appeared to be the most "basic" and these accordingly were assigned values of 10 units.

Michener and Sokal used a scoring system of assigning values or states of 1 to 8 to the characters, which allows some personal influence in classifying the expression of a character in one or another closely similar state, whereas in the present study, the transformed data obtained from the measurements of characters were used for the majority of the characters.

Results of Statistical Study

A total of 136 coefficients of correlation were calculated between pairs of the

TABLE II

CHARACTERS EMPLOYED IN PRESENT STUDY

1. Leaf shape (10)*
2. Width/length ratio of leaf (10)
3. Basal leaf angle(5)
4. Serration of leaf (5)*
5. Leaf pubescence (5)*
6. Number of hairs per 9 mm.^{2} of leaf surface (10)
7. Inflorescence type (5)*
8. Length of peduncle (5)
9. Number of flowers per inflorescence (10)
10. Color of corolla star (8)*
11. Diameter of corolla (10)
12. Orientation of sepals (8)*
13. Length of sepals (10)
14. Style type (8)*
15. Style length (10)
16. Anther length (10)
17. Pollen diameter (10)
18. Color of fruit (10)*
19. Diameter of fruit (5)
20. Number of seeds per fruit (10)
21. Number of sclerotic granules per fruit (5)
22. Diameter of seeds (10)
23. Shape of seeds (4)*
24. Height of plant (10)
25. Branching type (10)*
26. Plant habit (8)*

*Character scored arbitrarily.

TABLE III

MATRIX I OF CORRELATION COEFFICIENTS AMONG 17 TAXA OF *S. nigrum* COMPLEX.

Taxa	S. 103	S. 106	S. 109	S. 117	S. 126	S. 122	S. 127	S. 128	S. 129	S. 132	S. 133	S.135	S. 136	S. 140	S.143	S. 144	S.151
S. 103		.382	.320	.463*	.468*	.880**	.899**	.876**	.509*	.697**	.657**	.395*	.381	.603**	.666*	.473*	.899**
S. 106			.740**	- .063	.190	.317	.280	.269	.672**	.196	.202	.253	.245	.707**	.716**	.549**	.260
S. 109				- .027	.044	.154	.330	.286	.794**	.202	.084	.076	.012	.725**	.697**	.548**	.318
S. 117					.774**	.591**	.581**	.555**	.076	.569**	.718**	.500**	.488*	.069	.031	.056	.467*
S. 126						.726**	.466*	.406*	.182	.514**	.945**	.729**	.733**	.120	.104	.101	.503**
S. 122							.860**	.852**	.368	.761**	.809**	.510**	.506**	.229	.215	.291	.842**
S. 127								.922**	.407*	.614**	.684**	.359	.342	.575**	.557**	.362	.869**
S. 128									.669**	.558**	.607**	.414*	.420*	.455*	.440*	.434*	.907**
S. 129										.334	.214	.315	.298	.579**	.569**	.555**	.514**
S. 132											.406*	.526**	.466*	.352	.234	.039	.647**
S. 133												.773**	.787**	.326	.321	.317	.624**
S. 135													.980**	.101	.121	.331	.444*
S. 136														.061	.086	.320	.433*
S. 140															.993**	.617**	.533**
S. 143																.652**	.536**
S. 144																	.482*

*Significant at 95% level of probability.
**Significant at 99% level of probability.

17 different groups under study (Table III). These coefficients range from −0.063 for entries S. 117 and S. 106 (*S. americanum* and *S. amethystinum*) to 0.993 for S. 140 and S. 143 (two samples of *S. Douglasii*). Most of the statistically significant correlations are those between races of the same species, as expected. On the other hand, correlations which cannot be shown to differ from zero (not significant) generally show taxa morphologically less similar.

The first nucleus to be established was that between S. 140 and S. 143 which had the highest coefficient in the matrix, 0.993. After a survey of the taxa highly correlated with both members of this group, it was found that S. 106 (*S. amethystinum*) and S. 109 (*S. Leonii*) were the closest to S. 140 and S. 143 with $\overline{Ln} = 0.711$ (S. 106 × S. 140 = 0.707 and S. 106 × S. 143 = 0.716; S. 109 × S. 140 = 0.725 and S. 109 × S. 143 = 0.697).

The drop of this $\overline{Ln}$ is much larger than 0.040, hence no taxon was admitted to this group at this time. In the same manner, three more nuclei of two taxa each were determined: S. 135 and S. 136 (both *S. villosum*) with a correlation of 0.980; S. 133 (*S. nigrum*) and S. 126 (*S. Roxburghii*) with a correlation of 0.945. The last two were the first two separate species to be admitted to a nucleus. Another nucleus was formed by S. 127 and S. 128, both *S. nodiflorum*, with a coefficient of 0.922; the next highest average correlaton was for S. 151, also *S. nodiflorum* (0.888), which did not exceed the drop limit of 0.040, hence was admitted to the same nucleus; in the same way S. 103 and S. 122, the other two samples of *S. nodiflorum*, were added to this nucleus.

After the above computations, four taxa were still left without admission to any of the existing groups. A new matrix of coefficients of correlation was calculated using the coefficients of correlation of the newly formed nuclei and those of the four single species, using Spearman's method as suggested by Sokol and Michener (1958). After the third set of computations S. 144 (*S. gracile*) still did not have a high enough level of correlation to be attached to any of the three groups. Since its average correlations were higher with members of Group III it was finally added to this group.

By this procedure, three separate groups of species were obtained and they are shown in the scheme of relationships in Figure 1. The level of attachment of one species to a nucleus shows the amount of correlation existing with the

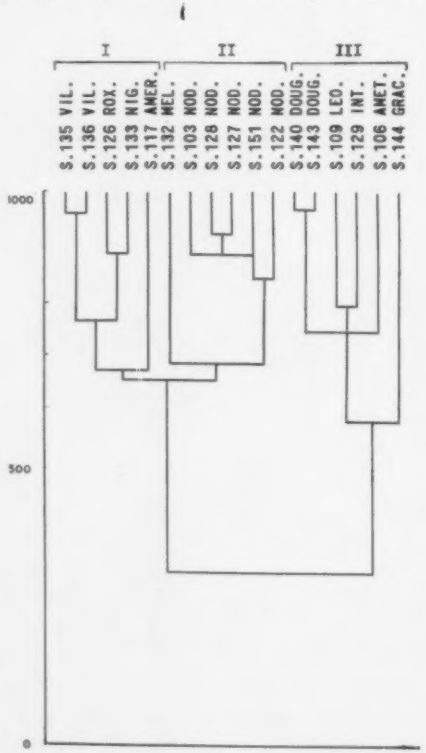

Fig. 1. Diagram of relationship of members of the S. nigrum *complex obtained by the variable group method for grouping correlations.*

other members of the group. The scale used in the graph contains the correlation values multiplied by 1000. It is possible to read directly in the scale the amount of correlation of each species in the group and between groups.

Group I includes the annual taxa *S. villosum, S. Roxburghii, S. nigrum* and *S. americanum*. The attachment of S. 135 - S. 136 to the original nucleus (S. 126 - S. 133) by a correlation of 0.776 was obtained in the second computation of correlations. At this time no other species was added in the group. Although S. 117 was the next candidate, its average correlation was significantly lower than the limit of drop. This species was admitted after a new computation of correlations.

Group II is formed by races of *S. nodiflorum* and species S. 132 (*S. melanocerasum*) which was admitted with a correlation of 0.690. The statistical drops of the correlations among the samples of *S. nodiflorum* are rather low, compared to those of the two samples each of *S. villosum* and *S. Douglasii*.

Group III contains tropical highland species (*S. amethystinum, S. Leonii* and *S. interandinum*) and subtropical species (*S. Douglasii* and *S. gracile*) of perennial semiligneous herbs.

A final matrix of correlations was computed in order to find the level of relationships among the three groups. Group I was closer to Group II at a level of correlation of 0.664 and Group III was united to both groups at the level of 0.308.

In the Michener-Sokal study, it was possible to compare the statistical results with those visualized by ordinary taxonomic procedures, since Michener had previously made careful studies of the group. Although no detailed taxonomic study of the species treated here had been done previously, it is nevertheless of interest to compare the relationships as determined by statistical methods with the impressions of the authors concerning relationships before the study began.

The species placed in Group I were thought to be closely related before the beginning of the statistical study. The two samples of *S. villosum* were quite similar and the high degree of correlation between them was expected. *Solanum Roxburghii*, however, was considered to be most closely related to *S. villosum*, and indeed, might well have been considered a subspecies of this species, but the statistical results show it to be more closely related to *S. nigrum*. Previous to the work of Stebbins and Paddock (1949) *Solanum nigrum* and *S. americanum* had been lumped under the former name or considered as merely varieties of a single species. In Figure 1, however, the low correlation secured would indicate that they are very different species. This situation perhaps can be explained by the fact that several characters, such as pollen, seed and corolla size, which are probably influenced by polyploidy, were taken into account in the present study.

Group II comprises *S. melanocerasum* and several different samples of *S. nodiflorum*. The authors both were of the opinion that the former species was not closely related to any other species since it had several unique characters and its relationship as indicated by Figure 1 could not have been predicted beforehand. Although this species has been confused with *S. nigrum* in the past, this probably indicates the lack of critical taxonomic study and does not indicate any close relationship. Since it is a hexaploid, however, it could conceivably contain a genome from *S. nodiflorum* which might account for its grouping with this species. The five strains of *S. nodiflorum* all fell in the same group as would be expected, but somewhat unexpected was the fact that the differences between them, as judged by the statistical method, were greater than those between certain species (*S. Roxburghii* and *S. nigrum*). The results

are not too surprising, however, when it is recalled that this species probably has the widest distribution of any taxon in the section and that considerable geographical variation might be expected. Probably this species should be considered as comprising several distinct subspecies. We do not feel, however, that our study is yet adequate to attempt to make formal taxonomic designations of these.

The third group in our opinion forms a fairly closely knit group which accords with our earlier taxonomic conclusions. The junior author (1955) had previously commented on the relationships of *S. Douglasii, S. amethystinum,* and *S. Leonii.* A very close relationship was also expected for the two highland species, *S. Leonii* and *S. interandinum. Solanum gracile* was thought to be more closely related to *S. Douglasii* and *S. amethystinum* than to the others. The statistical results show very close agreement to those which were expected from our initial impressions.

On the whole then, it can be stated that the results of the statistical analysis agree well with those from standard taxonomic judgments with a few exceptions. These conclusions are in agreement with those reached by Michener and Sokol (1957).

Hybridization Studies

Although it is now known that morphological divergence may not be accompanied by the acquisition of sterility barriers (Clausen, 1951 and Stebbins, 1950), the two often show some correlation. Therefore, it will be of interest to consider the results of hybridization in light of the relationships as determined by statistical procedures.

Reciprocal crosses between nearly all the accessions listed in Table I were attempted. In general, 20 flowers of each plant were pollinated in an attempt to secure hybrids. Fertility was measured by comparing the amount of the stainable pollen and the seed set of the hybrids with that of their parents. A detailed discussion of the morphology of the hybrids and their cytological analyses will not be attempted here. Hybrids between species having different chromosome numbers were largely unsuccessful or led to the production of highly sterile plants. For present purposes it will be more pertinent to compare crosses between homoploid species.

Diploid crosses. Crosses between the two members of *Solanum Douglasii* gave hybrids as fertile as their parents. In *Solanum americanum* crosses between S. 116 × S. 118 and S. 117 × S. 118 gave fertile hybrids and the cross S. 116 × S. 117 failed to set seeds. Crosses of the five strains of *S. nodiflorum* with each other, on the other hand, gave hybrids with a slight reduction in fertility over that of the parental strains, suggesting the development of incipient genetic isolation.

The results of the crosses between five of the diploid species are presented in Figure 2. The fertility of the hybrids secured varied from a reduction of about 25% in two combinations to about 75% in the hybrids between *S. americanum* and *S. nodiflorum.* Examination of Figure 2 reveals that there is no obvious correlation of the degree of fertility with the position of the plants in the statistical groupings of Figure 1. Crosses of the five diploid species with *S. Leonii* were all unsuccessful, but no great significance can be attached to this observation, for at the time the crosses were made the diploid form of *S. Leonii* had not been recognzed and it is possible that all crosses were made with tetraploid forms of *S. Leonii.*

At the polyploid level crosses were attempted between the four tetraploid species in all possible combinations. Crosses of *S. villosum* × *S. Roxburghii* gave hybrides with good fertility, and hybrids of *S. Leonii* × *S. interandinum* were secured which showed highly reduced fertility. Crosses of both *S. villosum* and *S. Rox-*

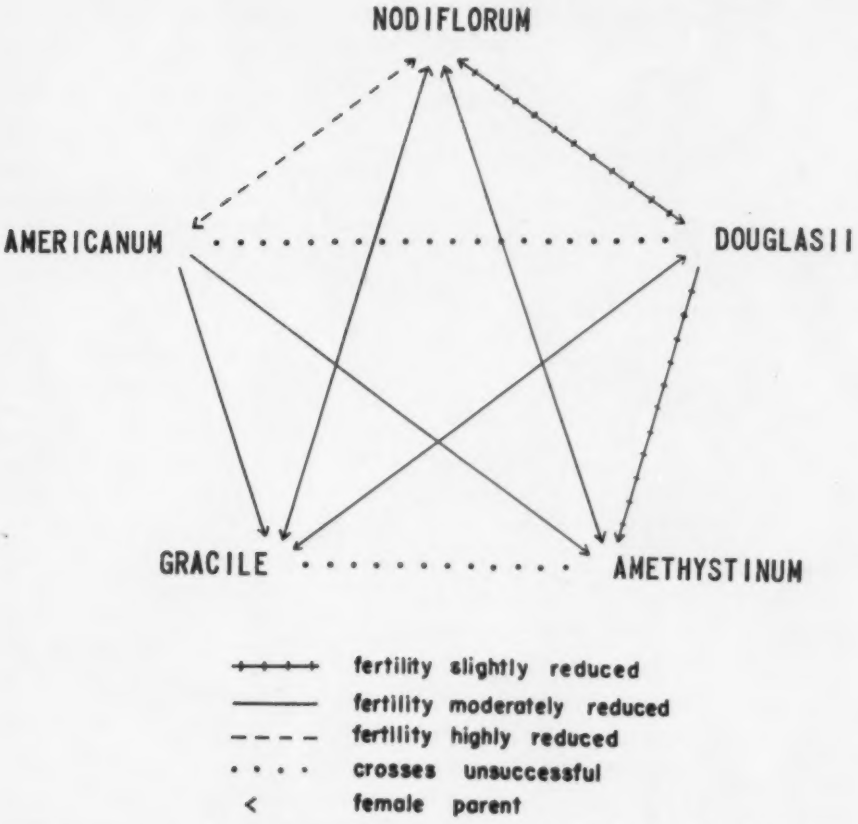

Fig. 2. Crossing polygon of diploid species of Solanum, *indicating fertility of F_1 hybrids.*

burghii with both *S. interandinum* and *S. Leonii* failed. Thus there is close agreement of the results of the hybridization with the position of the plants in the statistical arrangement — hybrids being secured between members of the same group and no hybrids being obtained between members of the different groups. Crosses between the two hexaploid species, *S. nigrum* and *S. melanocerasum*, which are placed in different groups, were unsuccessful, although Okabe (1937) has reported securing a plant with 48 chromosomes from such a cross.

Comparison of the results of the hybridization program with the groupings established by the statistical study reveals that the morphological relationship is paralleled by the "genetic" relationship established by the crosses for several of the plants, but that there are many exceptions, particularly among the diploid species. The latter, however, does not necessarily cast doubt on the validity of the statistical method but is probably indicative that morphological differentiation and development of sterility barriers do not necessarily go hand in hand.

Discussion

Sokal and Michener (1958) and Morishima and Oka (1960) have already discussed at some length the advantages and disadvantages of the statistical methods of studying relationships. Simpson (1961, p. 88) also has commented on the use of these methods. It will be necessary, therefore, to emphasize only certain points.

The results secured by means of correlation analysis by Michener and Sokol were in close agreement with those derived from the orthodox taxonomic procedures of Michener. In the present study, it is also felt that there is fairly close agreement of the results from the two methods. One then may ask if the additional time involved in the statistical study is worth the effort. An answer perhaps should not be attempted until more such studies are conducted, but it is clear that the method provides an excellent check on ordinary taxonomic procedures, and if disagreement is found, a re-evaluation of the previous taxonomic conclusions is in order.

Our example of the possible usefulness of the correlation analysis relating to the present work may be given. Nakamura (1937) and Stebbins (1950) have suggested that two genomes of the diploid *S. nodiflorum* are present in the chromosome complement of the hexaploid *S. nigrum*. If this were true, one would almost certainly expect *S. nigrum* to fall into the same group as *S. nodiflorum*. The only diploid species now known in the group with *S. nigrum* is *S. americanum* which in so far as is known occurs only in North America, whereas from present evidence *S. nigrum* appears to be of old world origin. The geographical distribution provides somewhat of a dilemma if *S. nodiflorum* is to be considered an ancestor of *S. nigrum*, but the statistical findings point up the fact that the origin of *S. nigrum* needs restudy.

The greater number of characters and the scoring method used by Michener and Sokal probably resulted in higher magnitudes of correlations at the species level than those obtained in the present study. It seems also that in the present work the weighting of characters at the time of standardizing the data induced some deviations from the normal distribution of the values of these characters which affected to some extent the magnitude of the correlations; but, since the same error was introduced for all the characters, the results are still considered valid. Michener and Sokal state that not fewer than 60 characters should be used, but this number is difficult to secure when comparing a small number of very similar species. Since the magnitude of the correlations was not considered as important as the grouping of the species, the use of a small number of characters does not seem to us, however, to be a serious error.

The scoring system employed in this investigation has the advantage of using the actual data obtained from direct measurements instead of scoring with purely arbitrary scales which was done by Michener and Sokal. However, the introduction of arbitrary scores for certain qualitative characters hinders the complete elimination of subjective elements in the present study. The scoring of qualitative characters offers certain problems. For example, since nothing is known of the genetics of flower and fruit color, the scaling of these characters may particularly be open to some criticism. Moreover, the use of certain characters which are probably influenced by polyploidy may be questioned.

In the present study we are dealing with diploids, tetraploids, and hexaploids. Since in all probability some or all of the polyploids have had their origin from different diploids, the pattern of evolution would be reticulate. The present scheme (Fig. 1), while not necessarily intended to be phylogenetic, fails to por-

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Summary

A comparative study was made of eleven species of *Solanum* (*Morella*), mainly from tropical America. Through a statistical analysis of correlation of 26 characters of each species by the "variable group method" a scheme of relationships was determined. Three groups of related species were recognized: Group I *S. villosum, S. Roxburghii, S. nigrum,* and *S. americanum;* Group II *S. melanocerasum* and *S. nodiflorum;* Group III *S. douglasii, S. Leonii, S. interandinum, S. amethystinum,* and *S. gracile.* The relationships derived from the statistical method showed rather close agreement to those expected from ordinary taxonomic procedures.

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Although the statistical method used here is extremely time consuming, it appears to offer some advantages and is deserving of a wider trial. The use of the statistical method minimizes the subjective element in plant taxonomy, but the exercise of taxonomic judgment is still necessary in the selection and evaluation of characters and in the final interpretation of the results.

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Ashwagandha—An Ancient Indian Drug

Ashwagandha, the root of* Withania somnifera *Dunal, is an ancient drug used in India by practitioners of Ayurvedic mediicne and as a household remedy. The drug is now official in the Indian Pharmacopoeia. Results of a survey regarding the cultivation, collection and marketing of this drug are described.

C. K. ATAL[1] and A. E. SCHWARTING[2]

The authors first became interested in Ashwagandha in 1954 because of its use as a sedative in the Ayurvedic system of Indian medicine. In order to undertake studies on this drug, roots were collected from wild-growing plants of *Withania somnifera* Dunal, the supposed source of Ashawagandha, besides procuring commercial samples from various drug markets of India. It was observed (2) that the authentic roots from wild plants differed from the commercial roots in certain external and internal characters and it was suggested that the commercial roots were probably derived from cultivated plants. This assumption was based on the fact that the commercial roots were extremely uniform in size and such uniformity could not be expected from wild sources of a perennial shrub. It was also suggested that the anatomical differences shown by the commercial roots might be due to some distinct varietal status of the cultivated plants. Inquiries made of retail and wholesale drug dealers about the origin of commercial Ashwagandha roots provided no useful information, partly due to lack of cooperation on the part of the traders and partly due to the fact that they themselves did not know the origin of the drug.

In 1959 while examining the file containing the herbarium specimens of *W. somnifera* at the Forest Research Institute, Dehradun, a letter was found which gave the first clue about the place of cultivation of Ashwagandha. The letter dated May 5, 1911, written by Mr. W. F. Wibcoe to the Director of the Forest Research Institute, indicated that *W. somnifera* was under cultivation at Manasa in Indore state. Consequently, in March of this year a trip was undertaken[3] to Manasa (now included in Madhya Pradesh state) to collect information about the cultivation, collection and marketing of Ashwagandha and to determine if the cultivated plants differed from the common wild plants.

Uses and Constituents

Ashwagandha is used throughout India as a safe home remedy as a tonic in geriatrics, being efficacious in relieving hand and limb tremors of elderly people. It is prescribed for all kinds of weaknesses and is supposed to promote strength and vigor, being regarded as an aphrodisiac and rejuvenator. It is the drug of choice among the Ayurvedic physicians in the treatment of rheumatic pain, inflammation of joints and certain paralytic conditions. There are a number of proprietary preparations of this drug used for all types of nervous disorders and as sedatives in the treatment of insanity and in hypertension. The leaves of *W. somnifera* are used as a local application for all types of skin lesions, ulcers, boils, and swelling, to reduce pus formation, inflammation and to promote healing processes.

Ashwagandha is mentioned in the ancient texts of Ayurveda. Punarvasu

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Atriya, an ancient scholar who taught medicine at the Taxila University in Punjab about 1000 B.C., mentioned numerous uses for this drug. Another famous physcician, Charaka, who lived about 100 B.C., advocated various uses of this drug and prescribed it for hiccup and in female disorders.

Some of the reports about the usefulness of this drug are contradictory. Trebut [cf. (2)] reported that the drug contained an alkaloid and possessed hypnotic properties. The drug was used (1) as a hypnotic in the Government Hospital, Algiers. Power and Salway (13) investigated the roots of south African origin and isolated an amorphous alkaloid. However, they failed to observe any marked physiological activity when either the whole drug or the isolated base was administered to dogs. Twenty years later Majumdar and Guha (11) isolated three amorphous bases from a Bengal source of the drug and confirmed the presence of constituents previously reported (13). Majumdar (12) in a recent publication reported the isolation of eight brown alkaloids, one of which was nicotine. Moreover, he reported that the major alkaloid withanine possessed a marked sedative and hypnotic action. In a study of the fruit juice Kopaczewsky (6) reported the milk coagulating property and also isolated a hypnotic fraction. However, Neuwald (10) observed no adrenolytic or sedative action when the total alkaloid extract of the drug was injected into anesthetized cats. Haddad (3) fed the leaves of Egyptian plants to rabbits and hens and concluded that there was no physiological action. Malhotra, *et al.*, (8) have shown that the total extract of the drug exhibits marked sedative action on mice, rats, rabbits, dogs, and monkeys and a relaxant and antispasmodic action on ileal and tracheal muscles. These authors showed this drug to potentiate the action of pentobarbital sodium, and also (9) that an extract of Ashwagandha has prolonged hypotensive, bradycardiac and respiratory stimulant action. Kurup (7) isolated an antibiotic principle from the leaves of Ashwagandha. Rother, *et al.*, have presented chromatographic evidence (14) for the presence of eleven alkaloids in the root.

The Plant

There is evidence of considerable morphological variation in the species and need for systematic work on the various morphological and geographical forms. The wild plants are generally erect branching shrubs, up to one meter in height. All the overground parts, especially the stem, the veins, and the calyx, are covered with a sparsely hairy tomentum. The leaves are simple petiolate, ovate, exstipulate, entire, acute and glabrous. The leaves on vegetative shoots are alternate and large while those on floral branches are opposite, arranged in pairs of one large and one small leaf and the members of the pair, arranged somewhat laterally, have in their axil a cymose cluster of 5 to 25 inconspicuous pale green flowers. Flowers are short-pedicellate 4-6 mm in diameter, gamosepalous, sepals 5-parted, persistent, with acute linear lobes. In the fruiting stage the calyx becomes enlarged, inflated and completely encloses the fruit. Corolla gamopetalous, 5-lobed, lobes spreading or recurved, acute pubescent and greenish yellow; stamens epipetalous, arising from the base of petals; filaments slender; anthers innate and oval. Gynoecium syncarpous· composed of minute swollen ovary subtended by a long slender style. Fruit, a berry enclosed in the green persistent calyx, is 5 mm in diameter, green when unripe, orange-red when mature enclosing numerous small capsicum-like seeds.

The cultivated plants are morphologically distinct from wild plants. According to Kaul (5) the cultivated plants are "different from the wild ones not only in their therapeutic properties but in all

Fig. 1. A cultivated plant of Withania somnifera.

morphological characters like roots, stems, leaves, flowers, pollen grains, mature fruits, seeds and the enlarged calyx." He has suggested the name *Withania ashwagandha* for cultivated plants. Our observations agree with those of Kaul (5) except that we failed to find an enlarged calyx in the cultivated plants. In fact, we have observed that the calyx in cultivated plants is less than one-half as large or inflated as in wild plants growing at the Panjab University campus. It should be emphasized that cultivated plants are rarely taller than 30 cm (Fig. 1).

Geographical Distribution

In addition to the recent description (5) of *W. ashwagandha* Kaul, two species of *Withania* have been described (4) on the Indian subcontinent. *Withania coagulans* Dunal, a xerophytic species, grows wild in Baluchistan (now Pakistan). This species is also reported from Sutlej Valley in the Indian Punjab but has not been observed there in recent years. *Withania somnifera* Dunal is of widespread distribution throughout northwestern India, Bombay, Gujrat, Rajasthan, Madhya Pradesh, western Uttar Pradesh and Punjab plains to the mountain regions of Punjab, Himachal Pradesh and Jammu, ascending to a height of 5000 feet.

Outside India this species grows wild in Pakistan, Afghanistan, Palestine, Egypt, Jordan, Morocco, Spain, Canary Islands, eastern Africa, Congo, Madagascar and South Africa. These areas represent wide variations of soil, rainfall, temperature and altitude.

Cultivation

Except for a limited collection of roots from *W. somnifera* plants growing wild in the Bikaner and Pilani area, the supplies of Ashwagandha roots are obtained exclusively from cultivated sources. Although it is believed that the Manasa plantations originated in the last decade of the nineteenth century, earlier supplies

Fig. 2. A field of Withania somnifera *near Manasa.*

of the drug came from Nagore, a few hundred miles away in the adjoining state of Rajasthan. The Nagore drug was evidently from wild plants and today enters commerce to a limited extent. However, the drug from Manasa is sold under the name Ashwagandha Nagori (Ashwagandha of Nagore), a rather misleading suffix. In 1911, when Wibcoe visited Manasa, about 400 acres of land were under Ashwagandha cultivation. At the present time the fields of Ashwagandha occur in a radius of eight miles, with Manasa as the center, covering an area of about 4000 acres. In certain years the acreage is considerably increased. Some of the villages in this cultivation area are Anspur, Aler, Pipliaroaji, Nalkera and Sawan. In those years when there is demand for the drug and the prices are high, the cultivation extends beyond these boundaries to Rewli-Devli, a village 14 miles from Manasa.

A lesser known and less important center of Ashwagandha lies in the adjoining state of Rajasthan, where a limited cultivation may be seen near Arnod in the district of Partapgarh. When prices are high the area under cultivation in this region is considerably enlarged.

Cultivation of Ashwagandha is not a very profitable enterprise for the farmers. They obtain a smaller monetary return per acre than from the main crops of opium poppy, wheat, gram, linseed, ajowan or soy. Yet the farmers persist in Ashwagandha cultivation since this crop requires little attention or labor and harvesting and marketing succeed the above crops. This crop is grown on soil which is unsuited for other crops.

The seeds are sown in June or July just before the onset of the rainy season. An average of 5 pounds of seed is sown per acre but the amount is increased in rich soil and decreased in the case of poor soil. Sowing is done by broadcasting. Special preparation or care of the land is not practiced; manuring or weeding is not done (Fig. 2). In fact, addition of fertilizers such as ammonium sulfate produces plants with heavy leaf growth and small root yield. In some cases if the seedlings do not appear healthy and vigorous, the farmers recultivate the soil and sow other crops. No irrigation is required throughout the growth period. Excessive rain is harmful because it leads to extensive weed growth. The plants flower and fruit in December and January; harvesting is started in January and continues into late March.

Collection and Preparation

The entire plants are uprooted for the collection of roots. Usually contract labor is employed and the laborers receive Rs. 4.00 per man for each 82 pounds of washed and cut fresh drug. The roots are separated from the overground parts as

Fig. 3. A drying area and purchase site for Ashawagandha.

Fig. 4. The root of Withania somnifera *being cleaned of adhering soil by beating. This process also removes the small brittle lateral roots.*

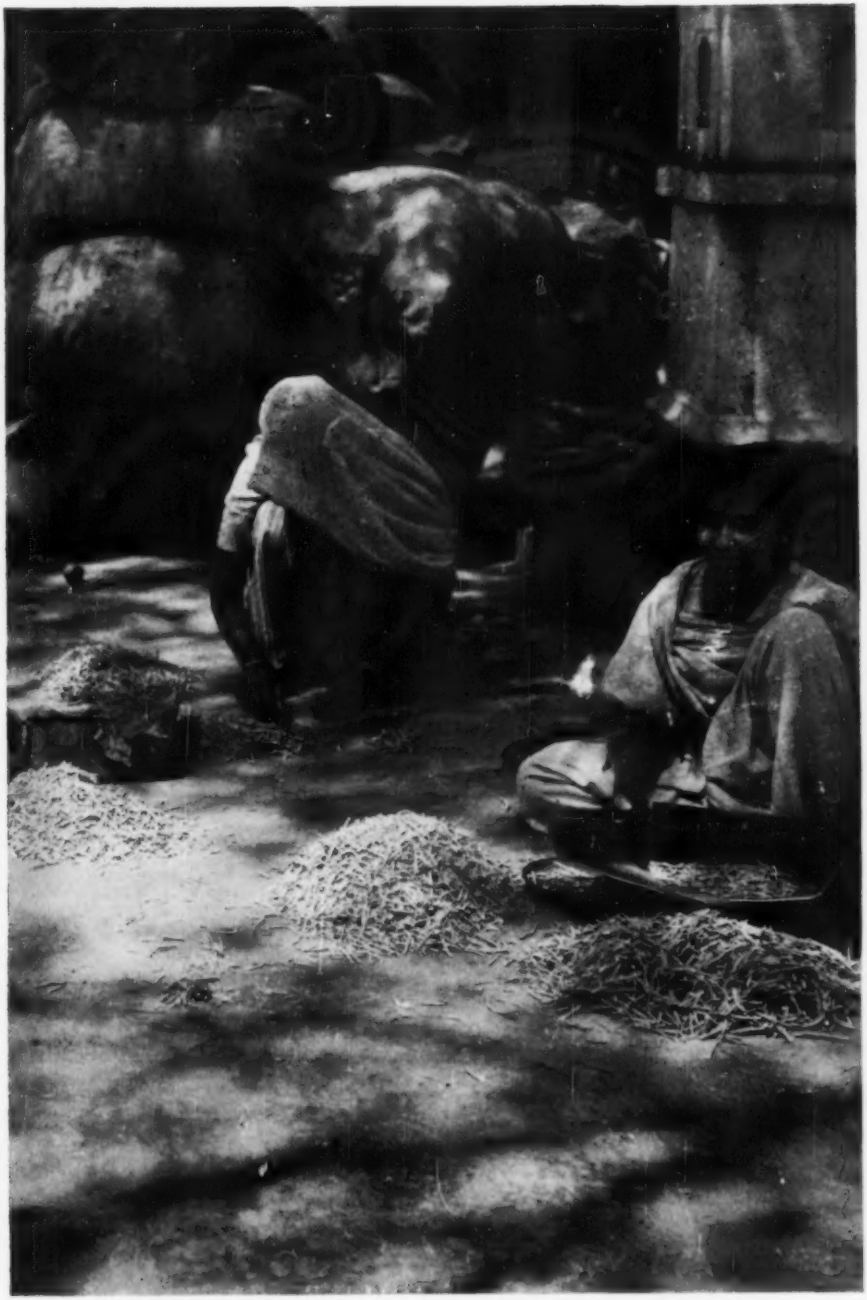

Fig. 5. The grading process of Ashwagandha.

soon as possible after collection by cutting the stems 1-2 cm above the crown. The entire root system along with the remains of aerial stems is either cut transversely into smaller pieces or dried in the whole in the sun. The yield, per acre, is about 500 pounds of fresh roots which reduces to about 150 pounds upon drying. In exceptional cases up to 300 pounds of dry roots per acre may be obtained and virgin soil usually gives greater yields. The Manasa area produces about 656,000 pounds of dry roots annually and in peak years the production may reach three times this figure.

The entire root production of the area is brought to Manasa (Fig. 3) where it is purchased by a number of wholesale buyers who deal almost exclusively in Ashwagandha. Certain dealers own their own Ashwagandha fields or purchase entire standing crops before harvest. The roots either in the whole dried condition or transversely-cut dried pieces undergo further cleaning, trimming and grading before they are dispatched to the various drug markets of India. The entire roots are beaten (Fig. 4) with a club which removes adhering soil and breaks off the thin, brittle lateral rootlets. The main tap root is cut into transverse pieces 4-8 cm long. Lateral branches, root crown and stem remains of other roots are carefully trimmed with the help of a special knife ("Sarota," used in India for cutting betelnuts). These workers receive Rs. 0.36 for processing each basketfull (about 5 pounds) of drug.

The produce at Manasa is carefully hand-sorted into different grades (Fig. 5). Although there is no clear distinction among the various grades, the following differences may be recognized.

Grade I. — This is represented by roots 1-1.25 cm in diameter and more or less uniform in size, nearly cylindrical or at the most slightly tapering. Their external surface is almost smooth and very light in color, with a clear white starchy fractured surface which shows a non-woody xylem. This grade is devoid of any root crown.

Grade II. — This is similar to grade I except that the roots are thinner in diameter (0.5-1.0 cm) and have occasional rough and dark outer surfaces.

Grade III.—These are roots of varying diameter showing a wrinkled light brown surface and a splintery starchless fracture. These represent roots in which a hard lignified xylem is present.

Grade IV.—These are thin long wiry roots rarely exceeding 3 mm in diameter. This grade is practically useless as a drug.

In addition a number of intermediate grades are made by the dealers by mixing the above grades in different proportions and also by incorporating the root crowns and remains of aerial stem bases. As a result of the existence of these grades the drug may be purchased at prices ranging from Rs. 5.00 to 70.00 per 82 pounds. Grade I roots are sold at an average wholesale price of Rs. 60.00 per 82 pounds but the price is subject to variation from year to year.

Marketing

The Manasa dealers have a monopoly for the supply of Ashwagandha throughout India. They either receive orders directly from the wholesale crude drug dealers from different parts of India or supply the drug through a number of commission agents located in the town of Neemuch about 18 miles from Manasa. Of the total production about 50% is sent to Bombay, 20% to Calcutta, 20% to Delhi and the remainder to Amritsar, Kanpur, and Katni markets. Except for Bombay the demand in other markets varies considerably from year to year. Parts of southern India receive their supply indirectly via the Bombay market.

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Mosses in Japanese Gardens

ZENNOSKE IWATSUKI[1] and TSUTOMU KODAMA[2]

Introduction

In the United States, Grout (1931) wrote of the use of mosses in landscape gardening, citing as an example the planting of mosses to beautify grounds on the Cutting Estate at Great River, Long Island, New York. He stated "the soft beauty of coloring imparted to a landscape or a roof by a covering of variously shaded mosses has always been appreciated by artists and other lovers of beauty. . . . in recent years a number of wealthy people have endeavored to increase the charm of their shaded walks by encouraging the natural growth of mosses and by transplanting suitable species." Japanese people have also used the mosses as an element of beauty in their gardens for a long time.

The traditional Japanese gardens are quite different in style from occidental ones. The former usually have no geometrical considerations and stay within natural forms and harmonize with them. Japanese gardeners attempt to express natural beauties in their gardens to alleviate the drabness of city life. However, Japanese gardening is not a mere imitation of nature, but it is a positive effort to create a natural beauty from man's standpoint. Although kinds and styles of gardens vary according to the builder's concepts of beauty and purposes, the most important element in the gardens is the arrangement of natural rocks and trees which are highly selected. Although the space in these gardens is usually small, they may try to create an atmosphere of being deep within the mountains and a feeling of tranquility of mind. In many of the Japanese gardens, bryophytes are used because they tend to create such an atmosphere. Much effort has been exerted by Japanese gardeners to obtain a more effective growth of mosses for the purpose of creating a better harmony and charm in the total garden.

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Temple Gardens

The most striking example of a moss garden in Japan is the one at Saihôji Temple which is usually called "Moss Temple" because of the abundance of mosses in the garden. Hundreds of people visit this garden to appreciate the beauty of mosses every year. The Temple is situated in the western part of Kyôto, central Japan. It was established in the eighth century, and later completed in the fourteenth century by the State Priest, Musô. The garden, with a rather large pond located in the center, occupies an area of about 3.2 hectares. Many trees and shrubs grow in the garden, but the ground under the trees is almost totally covered by a luxuriant growth of various kinds of mosses (Fig. 1).

Ishikawa, Okuda and Ishigame (1954) reported 50 species of bryophytes from this garden. However, as listed at the end of this article, the authors have studied the flora and recognized 92 species of bryophytes in the garden. Each species has its own environmental requirement, and each grows more beautifully in its own particular and suitable site. Among them, *Leucobryum neilgherrense*, *Polytrichum commune*, *P. formosum*, *Rhizogonium dozyanum*, *Dicranum japonicum*, *Brotherella henoni*, and *Bazzania japonica*, which singly or together may make unique and charming carpets, are the representative species. *Leucobryum* grows in

Fig. 1. View at the center of the garden of Saihôji Temple. The place is mainly covered by *Leucobryum*.

whitish-green, uneven mats beneath the trees (Fig. 2), while *Rhizogonium dozyanum* makes soft and thick, brownish-green velvet along the gate-path (Fig. 3). In open sites, green, lawn-like mats of *Polytrichum* are quite attractive.

Bryophytes Used

To make clear the composition of the moss-carpet, the authors studied it in detail, employing the quadrat method. The following table includes the bryophyte names, their coverage and frequencies in various types of moss-carpets found in this garden. These communities are not purely natural, because some of the weedy mosses undesirable for garden purposes are removed. For each sample plot in the moss carpets, 10 quadrats of 40 cm² in area were employed.

The sample plots in the table are as follows:

A Moderately humid, flat ground under the broad-leaved evergreen and pine trees. This type of moss-carpet has been most appreciated in the garden (Fig. 1).

B A place near A where the moss-carpets have been well kept only the last ten years. Composition of the bryophyte flora becoming similar to that of A.

C At border of the garden and less than ten years in age.

D More or less wet bank, under evergreen trees near gate. This type of moss-carpet is dominated by *Rhizogonium dozyanum* (Fig. 3).

Sample plots	A	B	C	D
Leucobryum neilgherrense	3 X	3 X	.....	1 VII
Bazzania japonica	3 X	2 X	x VII	1 X
Dicranum scoparium	x IV	.....	.....	.....
Brotherella henoni	x IV	2 X	1 X	2 X

Fig. 2. *Leucohryum neilgherrense* carpet in winter season.

Fig. 3. Gate and moss carpet along both sides of path at the entrance of Saihôji Temple. The carpet is dominated by *Rhizogonium dozyanum* and *Polytrichum formosum*.

Hypnum plumaeforme	x III	.....	.....	x III
Isopterygium textori	.....	x IV	.....	x III
Nardia sieboldii	.....	.....	5 X	.....
Pogonatum inflexum	.....	.....	x VI	.....
Atrichum undulatum	.....	.....	x IV	x II
Rhizogonium dozyanum	.....	.....	.....	2 X
Heteroscyphus bescherellei	.....	.....	.....	2 X
Calypogeia tosana	.....	.....	.....	x IV
Leucobryum scabrum	.....	.....	.....	x III

Coverage of each species was first measured in actual percent in each quadrat. These percental values of ten quadrats at the same sample plot were averaged and estimated by the following figures in this table: x = less than 1% ; 1 = 1-5% ; 2 = 5-25% ; 3 = 25-50% ; 4 = 50-75% ; 5 = 75-100%.

Frequencies of each species were estimated by the following figures: I = 0-10% ; II = 10-20% ; III = 20-30% ; IV = 30-40% ; V = 40-50% ; VI = 50-60% ; VII = 60-70% ; VIII = 70-80% ; IX = 80-90% ; X = 90-100%.

These types of moss-carpets are also found frequently in other Japanese gardens. However, at the Sanbôin Temple in Kyôto, there is a garden which shows another style of moss beauty. The large moss-carpets cover a circular area in a background of white sand. The contrast of green mosses and white sand is quite attractive. Although the garden is old, it shows a somewhat recent mode of gardening, which is often applied in modern Japanese gardens.

Moss Gardening

In order to make nice moss-carpets and preserve them for a long time, we should consider at first the environmental factors in the garden where the mosses grow. A relatively high water table, high humidity and moderate light intensity are the most important and desirable conditions. The growth of mosses at "Moss Temple" seems to indicate factors there are quite satisfactory for the mosses.

The mosses in the Japanese gardens are partly natural and partly transplanted from the mountains. Gardeners say that some kinds of mosses are sold at certain nursery shops in large cities. These mosses are planted by various methods. If material is abundant, it is usually planted on hardened and previously-irrigated ground in much the same way we plant a lawn. Species of *Pogonatum* such as *P. inflexum* which is one of the commonest mosses in open sites at low elevations in Japan, is dried and mixed with soil, which is then scattered on the ground and pressed. In any case clay soil is more suitable than a sandy one for the mosses.

A wise selection of suitable species is necessary for success in making a moss garden. If the environment is suitable, certain species of mosses grow excellently. After a period of time, some undesirable weedy bryophytes such as *Marchantia polymorpha*, *Conocephalum conicum*, *C. supradecompositum*, *Phaeoceros* spp., *Hypnum plumaeforme*, etc., will migrate into the carpets. In many gardens, these species, as well as other weedy vascular plants are usually cleaned out to keep this carpet pure.

In the finished gardens, the moss-carpets are always kept clear of dead leaves of trees and other debris by frequent sweeping. Damaged portions should be mended with new mosses brought from other sites. No fertilizer has been used for mosses.

At certain gardens in Kyôto, the moss-carpets are often covered by a layer of dead pine leaves in the winter season to protect the mosses from injury of the spiny frost. Some people admire this scenery with the cover of dead pine needles because it relieves the monotony of the same sights the whole year through.

Some people in Tôkyô who love moss culture are forming a club named "Aitai-kai" which means "moss-lovers club." This club consists of members who have various occupations, such as business men, doctors, owners of restaurants, etc. They plant many kinds of bryophytes in their gardens in pursuing their hobby. Although it may seem quite difficult to cultivate the bryophytes in such a crowded city as Tôkyô, many of the species are growing quite well.

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Appendix

A list of bryophyte species growing in the garden of Saihôji Temple (Moss Temple). * — Dominant species in this garden.

Musci

Sphagnaceae
Sphagnum palustre L.
Fissidentaceae
Fissidens japonicus Doz. et Molk.
Dicranaceae
Oncophorus crispifolius (Mitt.) Lindb.
Thysanomitrium richardii Schwaegr.
**Dicranum scoparium* Hedw.
Leucobryaceae
Leucobryum bowringii Mitt.
**L. neilgherrense* C. Muell.
L. scabrum Lac.
Grimmiaceae
Grimmia apocarpa Hedw.
Rhacomitrium heterostichum (Hedw.) Brid.
Bryaceae
Pohlia flexuosa Hook.
Mniaceae
**Mnium microphyllum* Doz. et Molk.
M. punctatum Hedw.
Rhizogoniaceae
**Rhizogonium dozyanum* Lac.
Bartramiaceae
Bartramia pomiformis Hedw. var. *crispa* (Web. et Mohr) B.S.G.
Orthotrichaceae
Orthotrichum consobrinum Card.
Macromitrium gymnostomum Sull. et Lesq.
M. makinoi (Broth.) Par.
Hedwigiaceae
Hedwigia ciliata (Hedw.) P. Beauv.
Cryphaeaceae
Forsstroemia trichomitria (Hedw.) Lindb.
Neckeraceae
Neckera humilis Mitt.
Thamnium sandei Besch.
Lembophyllaceae
Isothecium subdiversiforme (Broth.) Broth.
Theliaceae
Fauriella tenuis (Mitt.) Card.
Thuidiaceae
Haplohymenium triste (Ces.) Lindb.
H. pseudo-triste (C. Muell.) Broth.
Herpetineurum toccoae (Sul. et Lesq.) Card.
Thuidium cymbifolium (Doz. et Molk.) Doz. et Molk.
T. glaucinum (Mitt.) Mitt.
Brachytheciaceae
Rhynchostegium pallidifolium (Mitt.) Jaeg.
Entodontaceae
Entodon sullivantii (C. Muell.) Lindb.
E. rubicundus (Mitt.) Jaeg. et Sauerb.
Sematophyllaceae
**Brotherella henoni* (Dub.) Broth.
Clastobryella tsunodae (Broth. et Yasuda) Broth.
Sematophyllum japonicum (Broth.) Broth.
Hypnaceae
Ctenidium capillifolium (Mitt.) Broth.
Hypnum oldhamii (Mitt.) Jaeg.
**H. plumaeforme* Wils.
var. *minus* Broth.
Isopterygium textori (Lac.) Mitt.
I. tosaense Broth.
Hylocomiaceae
Hylocomium cavifolium Lac.
Diphysciaceae
Diphyscium fulvifolium Mitt.
Polytrichaceae
Atrichum undulatum (Hedw.) P. Beauv. var. *minus* (Lam. et D. C.) Web. et Mohr
Pogonatum inflexum (Lindb.) Paris
**Polytrichum commune* Hedw.
**P. formosum* Hedw.

Hepaticae

Blepharostomaceae
Blepharostoma minus Horik.
Lepidoziaceae
Bazzania albicans Steph.
**B. japonica* (Sde. Lac.) Mitt.
B. pompeana (Sde. Lac.) Mitt.
Lepidozia vitrea Steph.
Calypogeiaceae
Calypogeia arguta Mont. et Nees

C. tosana (Steph.) Steph.
Cephaloziaceae
Cephalozia bicuspidata (L.) Dum. subsp. *otaruensis* (Steph.) Hatt.
Harpanthaceae
Heteroscyphus argutus (Reinw., Bl. et Nees) Schiffn.
H. bescherellei (Steph.) Hatt.
H. planus (Mitt.) Schiffn.
Lophocolea minor Nees
Jungermanniaceae
Nardia sieboldii (Sde. Lac.) Steph.
Jungermannia plagiochildoides Amakawa
Scapaniaceae
Diplophyllum serrulatum (K. Muell.) Steph.
Scapania spinosa Steph.
Radulaceae
Radula constricta Steph.
R. japonica Gott.
R. oyamensis Steph.
Frullaniaceae
Frullania diversitexta Steph.
F. moniliata (Reinw., Bl. et Nees) Mont.
F. pedicellata Steph.
F. squarrosa (Reinw., Bl. et Nees) Dum.
Lejeuneaceae
Brachiolejeunea sandvicensis (Gott.) Evans
Cheilolejeunea imbricata (Nees) Hatt.
Lejeunea japonica Mitt.
L. punctiformis Tayl.
L. rotundistipula (Steph.) Hatt.
L. vaginata Steph.
Leptolejeunea subacuta Steph.
Cololejeunea japonica (Schiffn.) Hatt.
C. minuta (Mitt.) Steph.
C. kodamae Kamim.
C. orbiculata (Herz.) Hatt.
C. shikokiana (Horik.) Hatt.
Calobryaceae
Calobryum rotundifolium (Mitt.) Schiffn.
Pelliaceae
Pellia fabbroniana Raddi
Pallaviciniaceae
Pallavicinia longispina Steph.
Metzgeriaceae
Metzgeria conjugata Lindb. subsp. *japonica* (Hatt.) Kuwah.
Marchantiaceae
Monoselenium tenerum Griff.
Dumortiera hirsuta (Sw.) Reinw., Bl. et Nees subsp. *tatunoi* Horik.
Conocephalaceae
Conocephalum conicum (L.) Dum.
C. supradecompositum (Lindb.) Steph.
Rebouliaceae
Reboulia hemisphaerica (L.) Raddi
Ricciaceae
Riccia fluitans L.
Anthocerotaceae
Phaeoceros laevis (L.) Prosk.

BOOK REVIEWS

A World Map of Foodcrop Climates. Merrill K. Bennett. Reprint from Food Research Institute Studies, Vol. 1, no. 3, pp. 285-295. Stanford University, Stanford, California, 1960. $1.00.

This geographic-climatologic treatment of foodcrop distribution departs from traditional maps of world climate which show temperature an precipitation zones or which present climate as it is reflected in natural vegetation. The basis for the maps presented here is the differentiation of climates according to their relative hospitality to the unirrigated production of major foodcrops. When discussing criteria used in delineating foodcrop climates, the author very capably relates climatic factors to the foodcrops' growth requirements.

The value of this kind of mapping is particularly evident when the author points out that the zone which is too cold for the production of any major foodcrop comprises 29% of the world's land area but contains only .7% of the world's human population; and that 54% of the world's land area which is neither too cold nor too dry for foodcrop production contains 97% of the population. Such data taken with recent demographic projections can not fail to stimulate speculation regarding possible solutions of actual and impending competition for land surface between agricultural and non-agricultural human activities.

The two maps are twice-folded tip-ins of small scale. But the author does achieve, in map 2, by the use of six colors, stipples, and cross-hatches, the depiction of six foodcrop climates with three variations in rainfall. Map 1, in black and white, shows the foodcrop and non-foodcrop climates of the world.

LAWRENCE KAPLAN
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Chemical and Natural Control of Pests. E. R. de Ong. 244 pp. illus. Reinhold Publishing Corporation, New York, 1960. $7.50.

Pests are continually subjected to natural control forces. Supplemental chemical control is often necessary for high standards of agricultural production or public health. These natural forces — weather, resistant plants, insect diseases, insect predators, and parasites—must be understood before chemical control is resorted to. Misuse of insecticides may create major problems of reduction of beneficial forms, development of resistance to chemicals, and hazards of abnormally high residues.

Dr. de Ong's *Chemistry and Uses of Pesticides*, now in its second edition, served to compile information on the chemical and physical properties of pesticides and on their toxicology and compatibility. This new book, *Chemical and Natural Control of Pests*, is designed for the manufacturer, research worker, instructor, and farmer who must evaluate the two control methods. It is not a final guide. The status and usage change for various chemicals. Current recommendations should be checked with state experiment station workers or local agricultural officers. The background leading to the solution of many pest control problems is concisely stated and well documented with references in this well balanced presentation by Dr. de Ong.

JOHN E. CASIDA
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Madison, Wisconsin

Better Grassland Sward. Andre Voisin. 341 pp. illus. Crosby Lockwood and Son, Ltd., London, 1960. $8.00.

Better Grassland Sward is a delightful little book that was written by Mr. Voisin as a successor to his well known *Grass Productivity*. The book was originally published in French. The English translation was made by Catherine T. N. Herriott. *Better Grassland Sward* was published in French as *Dynamique des Herbages*, in German as *Lebendige Grasnarbe*, and in Spanish as *Dinamica de los Pastos*.

The book covers many phases of sward management. It begins with a discussion of basic ecology and ends with a quotation from Shakespeare—Hamlet tells his friend, "There are more things in heaven and earth, Horatio, than are dreamt of in your philosophy." The pages in between cover a variety of subjects from basic ecology to practical management. The book is divided into 16 parts with one to seven chapters in each part. The major sections include such division titles as: Static and Dynamic in Grassland Ecology, Methods of Surveying Pasture Flora, Sensitivity of Herbage Species to Cutting, Effect of Grazing Methods on the Flora, Influence of the Seed Mixture on the Flora of the Sward, The Effects of Animal Treading and Excreta Return, Effect of Light on the Plant Association, Soil Moisture and Grassland Flora, The Influence of Soil Acidity on Herbage Plants, Role of Phosphoric Acid, Potash, and Trace Elements in the Evolution of the Flora, Earthworms, Flora and Civilization. Other parts are on fertilizers, "depression," and cultural management.

The section on ecology is to be commended, not so much for the material contained, but for the service Mr. Voison has rendered in pointing out to the agronomist and sward manager that grasslands are dynamic communities that are affected by all factors of the ecosystem. Actually, grassland management is nothing more than manipulating the controlling factors of the ecosystem in order to reach and maintain a grazing equilibrium with a high amount of stored energy at the higher trophic levels. This fact has far too often been overlooked, and Mr. Voisin has done a service by calling it to the attention of those who read his book. However, his attempt to divide the ecosystem into static and dynamic factors may not be justified.

Much useful information is contained in the sections dealing with sward management and grassland production. It is unfortunate that the reader is referred so often to material in Mr. Voison's earlier book, *Grass Productivity*. Unless the reader has the earlier volume at hand, he may sometimes have difficulty in following the material.

"Earthworms, Flora and Civilization" is a most interesting collection of material about the "Lilliputian ploughmen," as Voisin chooses to call them. The material ranges from discussions of the effects of earthworms on soil and plant communities to a chapter in which earthworm distribtuion is used to substantiate the Wegner theory of continental drift. The chapter, "The Earthworm, Creator of Civilizations," covers worms from the ice age to the present. Once again Hamlet is quoted: "Did you know, Horatio, that without earthworms men could not create civilizations?"

The book is well documented, and the bibliography alone should be of interest to students of grassland swards. The references include 284 papers—some from every continent. The wide use of German and French papers should help give English-speaking technicians an idea of the work in the European countries. Two indices are given: one to authors, one to subjects.

This new book by Voisin is easily read and contains a wealth of information on the production of forages under sward conditions. Moreover, it is arranged in such a manner that it can be used effectively as a handbook. The reader who uses the book to increase his knowledge of pasture conditions will find the volume rewarding. However, the book is not a treatment of true grasslands, and the individual who goes to the volume for information on prairie or steppe may be disappointed. The English title, *Better Grassland Sward*, is much more descriptive than *Dinamica de los Pastos* or *Dynamique des Herbages*. The book should prove to be an interesting source of material for many pasture workers.

THADIS W. BOX
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Handbook of New Zealand Agriculture. J. W. Hadfield. 177 pp. Whitcombe & Tombs Ltd., Christchurch, 1959. 12s. 6d.

The title given to this slim volume is misleading, particularly if one thinks of a handbook as something approaching a comprehensive treatise. Not only would this book be more accurately described as a pocket dictionary but the subject matter, too, covers considerably less than the title implies, dealing with agricultural plants, their pests and diseases, and with soil problems, and excuding such topics as animal husbandry and

farm economics. Within these limitations, however, the author has performed a competent and worthwhile task. Alphabetically from Abundance oats and acidity to Zea and zinc, some 250 entries are clearly defined and described. Many cross-references help the reader to extract all relevant information.

A small pocket dictionary covering 250 items with an average of only two-thirds of a page per reference could easily be criticized for its omissions, brevity, and lack of balance. The book is primarily intended for people directly engaged in agriculture and for the general public whose knowledge of farming is only slight. Consequently, the topics of practical importance receive greater attention than those dealing with basic scientific concepts, and this appears reasonably justified. For example, such entries as colloids or hybrid vigor are dismissed in a few words, whereas a fair amount of space is devoted to pastures, tillage, or irrigation. Accuracy has at times been sacrificed, and few readers will agree with the definition of an isotope as an element that has been made radioactive. Because of these and other limitations imposed by the small size of the book, it would have been useful to have included a list of reference books and articles for further study.

However, despite these shortcomings the author has performed a useful task by bringing together a great deal of elementary and miscellaneous information into one small volume. This little book should serve as a source of reference for farmers, and it may provide others with readily accessible answers to simple questions relating to New Zealand crop and pasture plants, control of pests and diseases, and many soil problems. The author makes skillful use of his wide experience in agriculture, and, by and large, he has struck a reasonable balance between conciseness and accuracy.

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The Ecology of Soil Fungi. Edited by D. Parkinson and J. S. Waid. 324 pp. illus. Liverpool University Press, Liverpool, 1960. 42s 6d.

This book consists of the papers and discussions making up an international symposium on the ecology of soil fungi that was held in Liverpool in 1958. The United States, the Scandinavian countries, and Russia were among the countries not represented on the program. The emphasis of the program was on the dynamics of free soil fungi rather than on the counting and identification of fungi that can be isolated from soil. Mycorrhizal fungi and root-parasitic fungi were not included in the topics for the symposium.

The dilution plate method of enumerating soil fungi was both praised and criticized, but the anticipated debate on the validity or interpretation of the procedure was never realized during the discussions that followed the papers.

The book is divided into six sections: Methods for Isolation and Estimation of Activity of Fungi in Soil; The Growth of Fungi in Soil; Antagonisms in Soil; Dynamic Equilibria of Soil Populations; Problems Associated with the Decomposition of Organic Matter in Soils; and Physiology of Soil Fungi. Four to six papers are included in each section. Of particular value to the non-specialist, interested reader are these discussions: general fungistatis (unidentified to this day) of soil that results in the holding of the soil fungi (as spores) in a dormant state until the environment becomes suitable for growth; antibiotic production in the soil and its possible significance; mixing of fungi in soil via transport by soil fauna; the properties of a fungus that would favor its survival and dominance in soil; the interpretation of the various methods of isolating fungi and of *in vivo* studies of soil fungi; and the *in vivo* growth patterns of certain types of soil fungi.

The reader of this book will be left with the impression that he is now aware of almost all that is known about the ecology of free soil fungi, and he most certainly will be convinced that there really exists an ecology of soil fungi.

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Developments in Industrial Microbiology. Vol. 1. Edited by Brinton M. Miller. 267 pp. illus. Plenum Press Inc., New York, 1960. $7.50.

This is the initial volume of an annual

series to be published by the Society for Industrial Microbiology. This work is a record of symposia, special lectures, and contributed papers presented at State College, Pennsylvania, during the sixteenth general meeting of the Society in 1959. The goal of the Society is the advancement of microbiological sciences as they apply to industrial materials and processes. It seems very appropriate, therefore, that the first papers should relate to training for careers in microbiology as viewed by two academicians and an industrial microbiologist.

Space age microbiology is considered from the standpoints of gnotobiotics (pure cultures and germfree animals), radiation, algae and submarine habitability, algal gas exchangers, and finally the challenging role of the microbiologist on the team of scientists penetrating today's astronautical frontier . Other facets of industrial microbiology which are of increasing concern include self-sanitizing agents for fabrics, antitumor antibiotics, deterioration of proteins, and variation in microorganisms. In the latter paper *Neurospora*, yeasts, and bacteria are considered. Several symposia relate to hallucinogenic fungi, deterioration of wood by lower fungi, fungal metabolism, and fungicides. References are included with many of the papers. Although the book is printed by the photo offset process, it is very readable. The tables, graphs, figures, and pictures are generally clear. It would be helpful if an author and subject index had been included.

The final paper is the presidential address by Dr. C. L. Porter of Purdue University, "The Past and Future of the Society for Industrial Microgiology." In it he closes with a challenge hurled at most organizations at one time or another by a retiring president, namely, "to decide whether it wishes to become a historical statistic, to continue in mediocrity, or to go to work and achieve greatness." If the papers and authors included in this firse volume are an indication of the interests and caliber of the approximately 600 members, the Society is likely to become an outstanding specialized organization.

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Modern Insecticides and World Food Production. F. A. Gunther and L. R. Jeppson. 284 pp. illus. John Wiley and Sons Inc., New York, 1960. $8.50.

This book fills a long awaited need in the area of modern insecticides and their impact on world food production. It provides a general and comprehensive insight into the whys and wherefores of modern insecticides and acaricides, along with the problems arising from the use of these substances.

Fragments of the information contained in this text have been available previously in various scattered sources. The authors should be commended for having performed a rather excellent job of bringing together this infomation into a well organized, informative, and interesting presentation.

The text starts logically by discussing the insect and its host. This discussion, although somewhat general by necesity, gives a comprehensive picture of the complexities of insects and their behavior. Some excellent examples of plant damage and losses caused by insects are given. However, since this text is devoted to modern insecticides and world food production, it could have included additional data on insect losses, or on food production gains by the use of insecticides.

Chapter two brings into focus the various methods of insect control which are discussed under the two general headings of "natural control" and "applied control." Readers will realize the importance of the use of methods other than chemical control. Modern insecticides, their history and development, as well as the necessity of the use of such poisonous susbtances in connection with world food production are discussed in chapter three. Problems arising from the intensive use of insecticides are also presented.

Factors influencing effectiveness of insecticides are given in a very brief way. Insecticide formulations and their applications follow logically. Twenty-nine pages are devoted to the all important matter of insecticide deposits and residues. In a general way this topic has been thoroughly covered in a forward and unbiased but critical manner. Another pertinent point, that of resistance of insects to chemicals, has rated a separate chapter. The remaining nine chapters are devoted to an excellent discussion, ex

cept for an insecticide chemist or toxicologist for whom it would be largely too general, of acaricides, insecticides, attractants, and repellents. Insecticides are classified and discussed in groups as follows: organochlorine compounds, organophosphorus, petroleum, botanical, fumigant, soil treatment compounds, and others. The authors have included an interesting and worthwhile six-page discussion on botanical materials of potential entomological interest.

The text includes 57 illustrations, most of which are well done. Appendix A gives the approximate mammalian toxicities of insecticidal and acaricidal compounds mentioned in the text, in terms of LD_{50} values. Originators and some sources of modern insecticides and acaricides are listed in Appendix B. The common and scientific names of pests mentioned appear in Appendix C, arranged alphabetically by common names.

Although the number of cited references is limited, references are made to the more useful published reviews and other outstanding contributions and are listed following each chapter. In some areas, more detailed information or data would enhance the value of the book.

Although the book was not specifically designed for specialists in the fields of economic entomology and chemistry of insecticides, it will be welcomed by them and will be a genuine aid to workers in many fields of endeavor. It should have wide use and an enthusiastic acceptance by a large audience of readers since it discusses many aspects on the all important matter of world food production.

CHRIS C. BURKHARDT
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An Introduction to American Forestry. Shirley Walter Allen and Grant William Sharpe. 3rd ed. 466 pp. illus. McGraw-Hill Book Company, Inc., New York, 1960. $7.95.

An Introduction to American Forestry is the third edition of a text that was first published in 1938. It was designed for beginning students in schools of forestry primarily in the United States, and appears to have been extensively so used. It contains 446 pages of text, divided into 21 chapters and two appendices. These pages are followed by a rather comprehensive subject index. Selected bibliographies are found at the ends of the chapters. The book is copiously illustrated with photographs, maps, and diagrams.

The traditional structure of American forestry training, to which the student is being introduced with this book, is embodied in a five-point program. The major points of the program are silviculture, forest management the protection of forests, the economies of forestry, and the utilization of forests. One chapter (16 pages) of the present volume, called "Forestry that starts with bare ground," might be said to be devoted mainly to silviculture. Another chapter, also of 16 pages, is called "Forestry that starts with a forest," and might be interpreted directly as management. The field of protection, which has always had a large role in American forest practice, has 77 pages devoted to it, 35 of them to fire protection. The economics of forestry is given no special attention anywhere in the book. The whole problem of investment in American enterprises concerned with the development and use of forests, whether this investment is to be made by the public or by private interests, has two short paragraphs (92 words) devoted to it. The utilization of forests is discussed in a highly condensed chapter of 27 pages, which does not consider the recent explosive development of the ancillary uses of the forest that center in recreation. Thus approximately 135 pages of the text may be said to introduce the student more or less directly to four of the five main elements of his subsequent training. The fifth is avoided except through implication.

Certain other chapters deal with materials that are more or less fundamental to the student's understanding of the major elements. A chapter of 30 pages is given to the geography of American forests and is much condensed. Even more condensed is the chapter on "What a forest is" (14 pages). This small chapter is all the space that is allowed for silvics and forest ecology, which contain the core problems of silviculture and management, of much of protection, and of many of the modern recreational uses of the forest. These problems, most of them still far from solution, also define many of the pa-

rameters within which the economy of American forests must function. A large part of the work of American foresters has always been the measurement and evaluation of timber, and its extraction from the woods. Consequently it is not surprising to find relatively large amounts of space given to these subjects in the text: 30 pages to mensuration and 24 pages to logging. A chapter on "Beneficail influences and services" contains 30 pages, approximately half of which are devoted to a sort of "applied ecology." It is curious that it is the latter part of this chapter that contains a brief treatment (approximately 14 pages) of the recreational use of the forest.

A total of 128 pages of the text is used in these chapters on the basic and related subject matter of forestry. Together with the 136 pages on the four traditional technical fields, this makes 264 pages, or about 60 percent of the book, assigned to substantive forestry. The remaining 40 percent of the book is *about* the history of forests and forest practice in the United States, and about their present status. Forestry is regarded not merely as an art or an applied science, but as "a policy" (p. 84), and this is enlarged upon at length in two chapters (45 pages). Two other chapters (totaling 34 pages) describe the organization of federal and state forest services, and there is a further short piece concerning policy in a chapter on "Forestry and national planning." The practice of forestry on privately owned lands, which presents some of the most difficult problems faced by foresters in this country, is dealt with only briefly (22 pages) and is treated mainly with regard to larger holdings, which probably contain the lesser problems. A whole chapter of 20 pages, and four pages in an appendix, constitute a sort of guide to the student's forestry education and the acquisition of a professional job.

At several places in the book, but particularly in Chapter 5, which is mainly on definitions, forestry is said to be a "business." It is difficult to find out precisely what the authors mean by "business." On page 69 they imply that it has a "broad" meaning for them: of "things necessary to be done." On page 88 they list the "characteristics of Forest Businesses" as folows: "First, they are investments in productive resources; second,they are planned and ordered enterprises; third, they have been managed to yield returns in cash or kind, and are doing just this." Several examples of forest businesses are described on pages 69-78. All of these examples illustrate the three characteristics above mentioned. They represent invested capital and careful planning, and they yield returns. But in none of the examples are costs discussed in anything like realistic terms. In some cases the costs are not even mentioned. Consequently a genuinely discerning student will be constrained to question the actual solvency of these "businesses." If he is planning to practice forestry as a profession he will want to be assured that he can make a living at it, and if this is to happen there will have to be real returns from investments in the forest resource, private or public. No matter what definition of business he finds in *An Introduction to American Forestry,* the one he will use will be the one he will have to live by, and he will not be reassured by the examples given.

This is a crucial point in the book, a point upon which depends much of the book's effectiveness. It lies in the area that is avoided by the authors—the economics of American forestry. There are real issues in this area, and the beginning student should be informed about them. He should not be confused about the actual situation of the wood-using industries in the total economy of the country, and he should realize the vital significance of modern uses of the forest other than those involving the traditional uses of wood. He should be informed about the problems that must be dealt with before long-term investments of public funds for social benefits can be made realistically. He should be given some cases of private investment that show both costs and returns, and he should be made fully aware of the risks and uncertainties that attend a forest enterprise of any kind. He should not be required to take refuge in a definition of forestry that says it consists of "things necessary to be done."

If these matters were brought to his attention as cogently as they should be, it is inevitable that some other parts of this book would need to be raised to a higher level of

cogency. The actual kinds and distribution of American forest trees would need more attention than they get in the present volume, and the student should be far better informed than he is in this book about the limitations in our knowledge of the silvics of American forest trees. The whole area of utilization of wood products would need to be expanded, to introduce the student not merely to a few technological advances, but to make him more fully aware of the crucial position of research and development in this field in the American forest economy. Uses of the forest that involve aesthetic values would need much larger and firmer treatment, for it is in these values that the American professional forester may be finding a considerable part of his economic reason for being in the next few decades. If all these matters were given the attention they deserve, they could properly displace much of the 40 percent of this book that is *about* forestry but not *of* it, and the student would have a considerably better opportunity to judge his personal position with relation to American forestry.

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Light and Plant Growth. R. van der Veen and G. Meijer. 161 pp. illus. Philips' Technical Library, Eindhoven, Netherlands, 1959 (distributed by Macmillan Company, New York). $8.50.

Light and Plant Growth presents in six chapters and 161 pages a subject of wide interest to amateur and specialist alike. The book contains chapters on photosynthesis, phototropism, and photoperiodism. It is well illustrated with 92 figures and has a short list of references pertinent to each chapter.

The first chapter discusses some problems of light measurement for plant irradiation and defines the word "light" as used in the book. Light ordinarily refers to the wavelength region 4000 to 7000 A, but since some plant photoreactions occur in the ultraviolet and others in the infrared, the range included is 3000 to 8000 A. The occurrence in plants of several photoreactions, each with special wavelength dependence, makes necessary the characterization of light sources on the basis of their emission in the various spectral regions known to be active in the several plant photoreactions. Various methods of evaluation of light sources are proposed, and the advantages and difficulties in their use are considered.

Photosynthesis and phototropism each receive brief treatment in the next two chapters. The chapter on photosynthesis reviews the early history of the subject and briefly summarizes the present state of knowledge of the chemical nature of chlorophyll, energy transfer, the bio-chemistry of the intermediates, and the relation of other pigments to the phenomenon.

Phototropism, phototaxis, and photonasty are considered in Chapter 3. Early work of A. H. Blaauw, P. Fröschel, F. W. Went, and others is discussed. Action spectra for phototropism exhibit strong action in the blue, indicating a yellow photoreceptor such as carotene or riboflavin.

Photoperiodism is considered more fully than other phenomena. The flowering responses of long- and short-day plants are described and illustrated in some detail. Other phenomena influenced by daylength such as the onset of bud dormancy in woody plants, resistance to frost damage, production of storage organs such as bulbs and tubers, and the geographic distribution of plants are discussed.

In Chapter 5 the effects of different colors of light are described. The reversible red, far-red reaction is considered in connection with germination, flowering, stem elongation, and anthocyanin formation. Flowering responses of several plants subjected to colored light throughout the entire light period do not agree with those obtained when the plants are given natural light in the daytime and colored light as a dark-period interruption. This lack of agreement is not surprising because plants carry out several photochemical reactions, and when they receive light of only one color, it is reasonable to expect that some of these other reactions will not be satisfied.

The chapter on horticultural applications discusses the suitability of various kinds of lamps to special plant use, the construction of growth cabinets, the response of numerous horticultural plants to artificial light, and use of artificial light in the home.

The book is very useful for a wide range of readers. High school and college biology teachers will find in it many useful suggestions applicable to classroom or project work. The range of horticultural uses described should prompt growers to imagine and develop even wider use of light. Specialists studying photomorphogenic reactions of plants will find a stimulating array of plant responses described and figured in this small volume.

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